

*Dyslexie et troubles apparentés :  
un panorama des évolutions récentes en  
matière de concepts et de connaissances sur  
les mécanismes*

Michel Habib

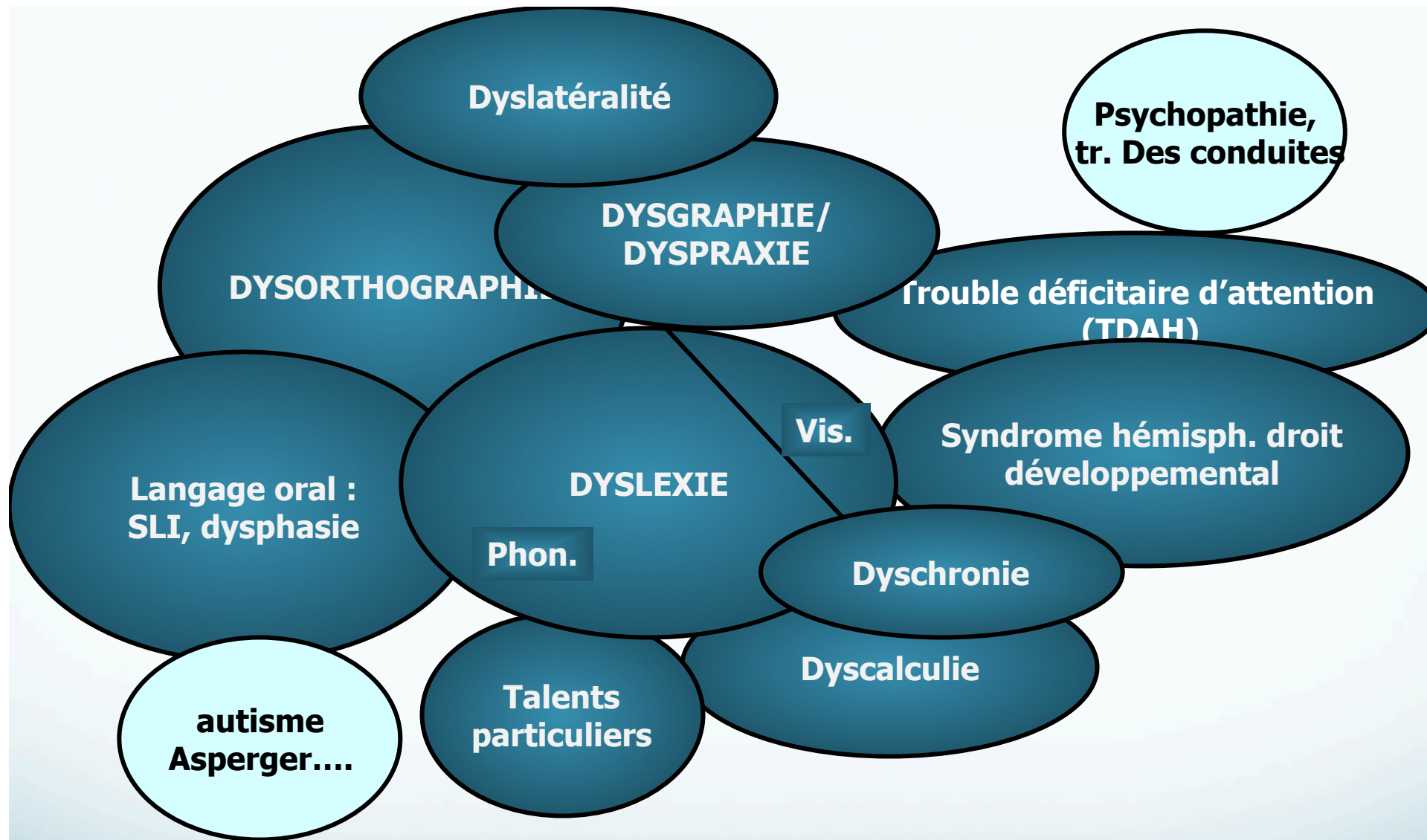


Fort-de-France, 27 avril 2015

# Plan de l'exposé

- Aspects terminologiques et nosographiques : qu'est ce que le DSM-5 a changé dans nos conceptions?
- Les théories de la dyslexie : apport de la neuro imagerie, revue de la littérature récente.
- Neuro développement et apprentissage : quelques considérations cliniquement pertinentes
- Rééducation scientifiquement ciblée de la dyslexie : Panorama des études scientifiques





*La « constellation dys » : un complexe symptomatique suggérant des mécanismes communs*

# DSM-5 : troubles spécifiques d'apprentissage

- A. Difficulté à apprendre et à utiliser les aptitudes académiques, comme indiqué par la présence **d'au moins un des symptômes** suivants, qui ont **persisté** depuis au moins 6 mois en dépit d'interventions ciblées:
- 1- lecture de mots inexacte, lente ou laborieuse
  - 2- difficulté à comprendre la signification de ce qui est lu (même si lu correctement)
  - 3- difficultés d'orthographe (spelling) : p.e. : ajout ou omission de lettres
  - 4- difficultés dans l'expression écrite (p.e. erreurs de ponctuation ou grammaticales, défaut d'organisation des paragraphes, manque de clarté de l'expression des idées)
  - 5- difficulté à maîtriser le sens des nombres, les faits numériques, ou le calcul
  - 6- difficulté dans le raisonnement mathématique (appliquer des concepts ou des faits dans la résolution de problèmes)
- B. Significativement en-dessous de ceux attendus pour l'âge et interfère significativement avec les performances académiques ou les occupations
- C. **Commence durant les années d'école mais peut n'être manifeste que dès lors que les demandes excèdent les capacités limitées de l'individu**
- D. Pas mieux expliquées par déficience intellectuelle, acuité auditive ou visuelle non corrigée, autres troubles neurologiques ou mentaux, adversité psycho-sociale...

DSM-IV: TROUBLES D'APPRENTISSAGE  
(CIM-10 : du développt des aptitudes scolaires)

Tr de la communication et du langage

Dysphasie (SLU)

Retard de parole/langage

DYSLEXIE

Tr. ECRITURE

DYSCALCULIE

Tr. de l'acquisition des coordinations

dysgraphie

dyspraxie

Autisme

Asperger

Précocité intellectuelle inhomogène

TDAH

CD

TOP

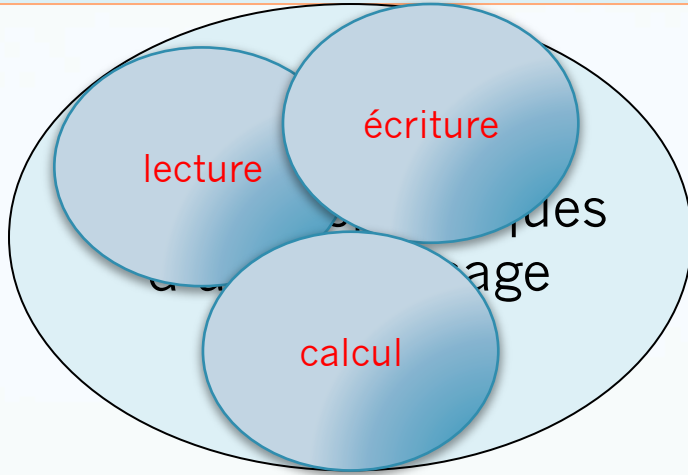
Troubles du spectre autistique

Troubles de l'attention et comportements perturbateur

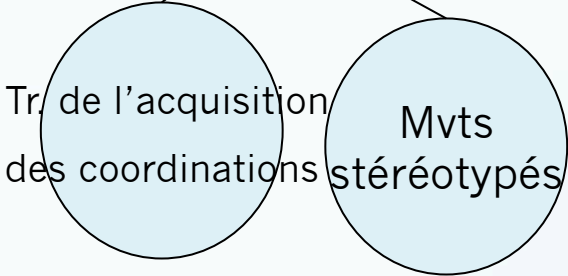
# DSM-5: TROUBLES neurodéveloppementaux

Déficience intellectuelle

Tr de la communication



Troubles moteurs



Troubles du langage

Trouble de production du langage (speech sound disorder)

Trouble (pragmatique) de la communication sociale

Disruptive, impulse control & conduct disorders

Autisme

Asperger

Troubles du spectre autistique

TDAH

CD

TOP

Intermittent explosive disorder

Trouble déficitaire de l'attention avec hyperactivité

# Caractéristiques communes aux syndromes "dys"

- Plus fréquents chez les garçons (sauf dyscalculie)
- Survient en général au sein de familles prédisposées (génétiquement?)
- Aucun facteur environnemental (e.g. périnatal) décelable (sauf TDAH)
- Atteinte "focale" d'un module neurocognitif (langage, lecture, calcul, praxies, cognition spatiale...)
- Intégrité de l'efficacité intellectuelle générale : QI normal ou supérieur
- Fréquence des associations comorbides : "multi-dys"
- Généralement responsables de handicaps d'intensité variable, notamment dans les apprentissages scolaires
- Le motif de consultation de loin le plus fréquent : trouble de l'acquisition du langage écrit

# Trois profils de "dyslexies"

- **Le syndrome phonologique** : le plus fréquent, le plus classique, repose sur l'hypothèse du déficit phonologique exclusif
- **Le syndrome visuo-attentionnel**: généralement considéré comme un déficit des processus d'ajustement de la fenêtre attentionnelle (S. Valdois)
- **Le syndrome dyspraxique** : moins connu, peut être associé aux précédents, mais aussi survenir seul

Peuvent s'associer entre eux!

# Le profil phonologique

- Dyslexie (incapacité à entrer dans la conversion grapho-phonémique)
- antécédent de difficultés de langage oral, SLI, dysphasie ou simple retard de langage, dyscalculie facultative
- Difficultés en lecture = déficit principal dans le décodage, erreurs de conversion grapho-phonémique, trouble de la conscience phonologique, trouble de la mémoire immédiate auditivo-verbale, trouble de la dénomination rapide
- Plus tard : difficultés d'ordre lexical et pragmatique
- WISC-IV :  $ICV < IRP$



# Le profil visuo-attentionnel

- La dyslexie : idem (incapacité à entrer dans la conversion)
- décodage exact mais lent ou paralexies dérivationnelles/sémantiques, substitution des "petits mots" (mots fonction), 2 types :
  - pas d'antécédents de trouble langage oral, conscience phonologique normale, trouble attentionnel aux tests, trouble de la mémoire de travail.
  - dyslexie "mixte", initialement phonologique évoluant ensuite vers un profil visuo-attentionnel (disproportion entre importance du déficit phonologique et intensité de la dyslexie)
- WISC-IV : altération IMT et IVT
- Fréquente comorbidité avec troubles comportementaux extériorisés : hyperactivité, trouble des conduites (conséquences à l'adolescence)

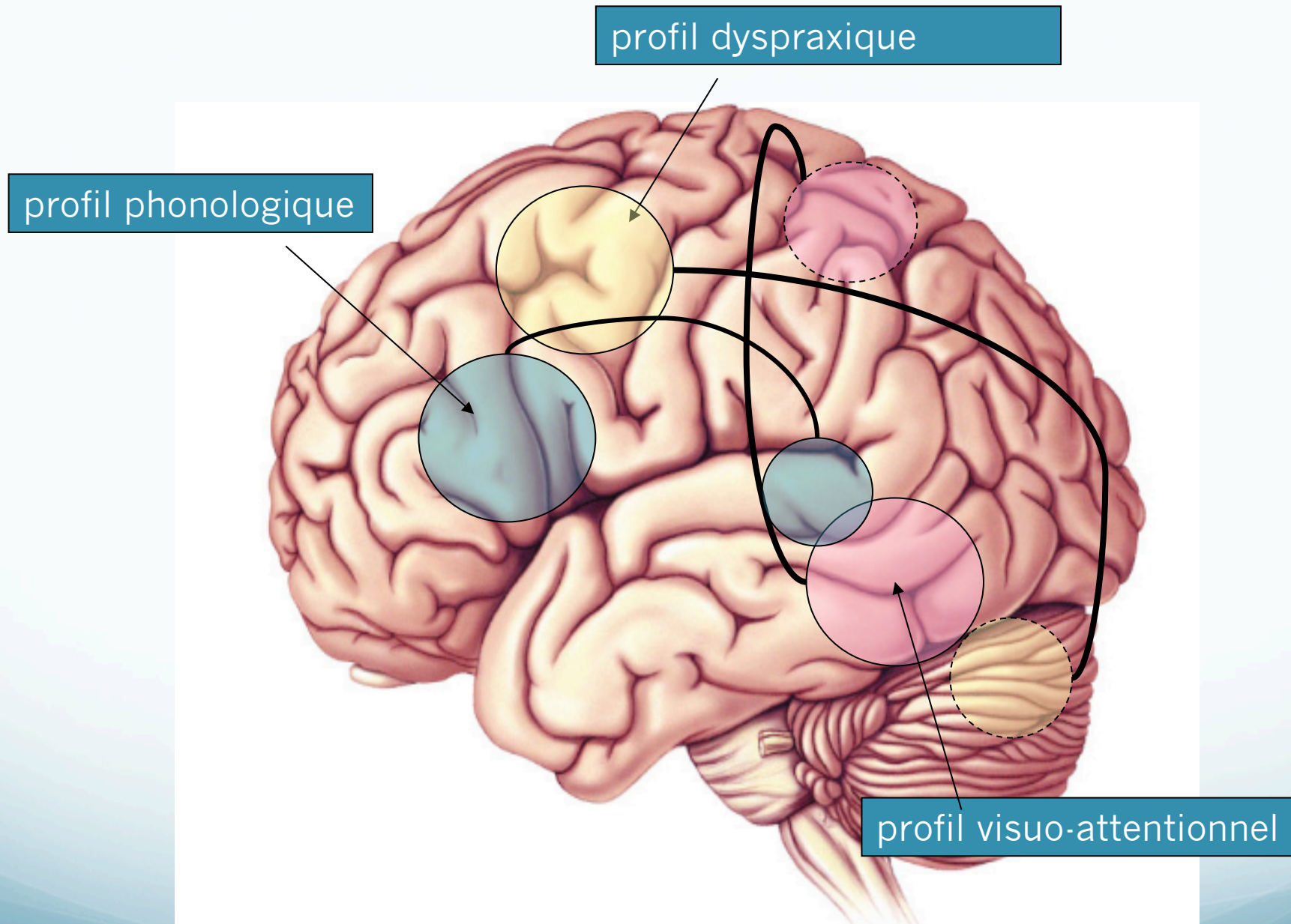


# Le profil dyspraxique

- Dyslexie en général plus modérée, volontiers erreurs visuelles
- retard des acquisitions motrices par rapport au langage, difficultés relatives dans les tâches de précision;
- dysgraphie, instabilité oculo-motrice, éventuellement trouble spatial, éventuellement dyscalculie spatiale,
- Dyschronie massive : appréciation d'une durée, placer un événement dans le temps
- éventuellement précocité intellectuelle,
- WISC-IV :  $IRP < ICV$
- $IVT \downarrow \downarrow$

# Chaque profil relève sans doute de mécanismes différents

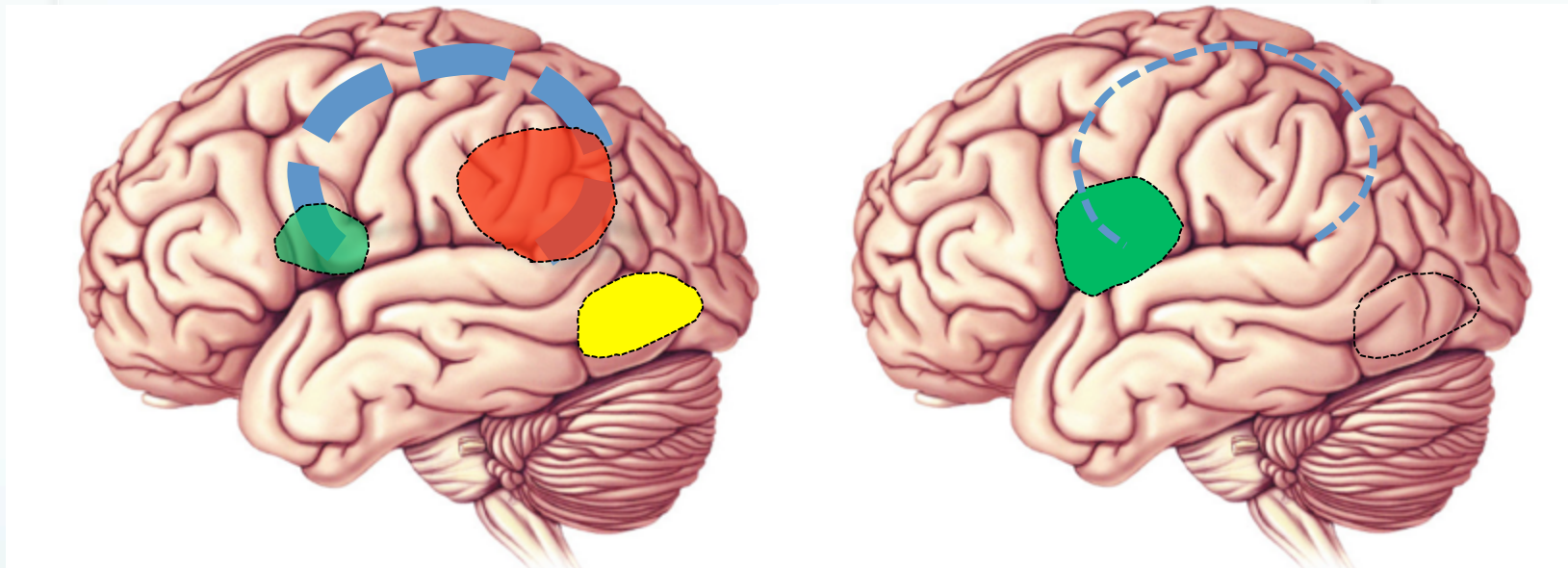
- Linguistique/phonologique : défaut d'installation des circuits du langage oral : aires péri-sylviennes gauches
- Visuo-attentionnel : défaut d'installation des circuits attentionnels et de contrôle de l'entrée visuelle : aires pariétales bilatérales et temporale inférieure
- Dyspraxique : défaut d'installation des circuits fronto-pariéto-cérébelleux



Substrat hypothétique des 3 principaux profils des troubles « dys »

# Dyslexie : les causes et mécanismes

Dyslexique



Le cerveau dyslexique (trouble phonologique): défaut d'activation et de connectivité dans l'hémisphère gauche



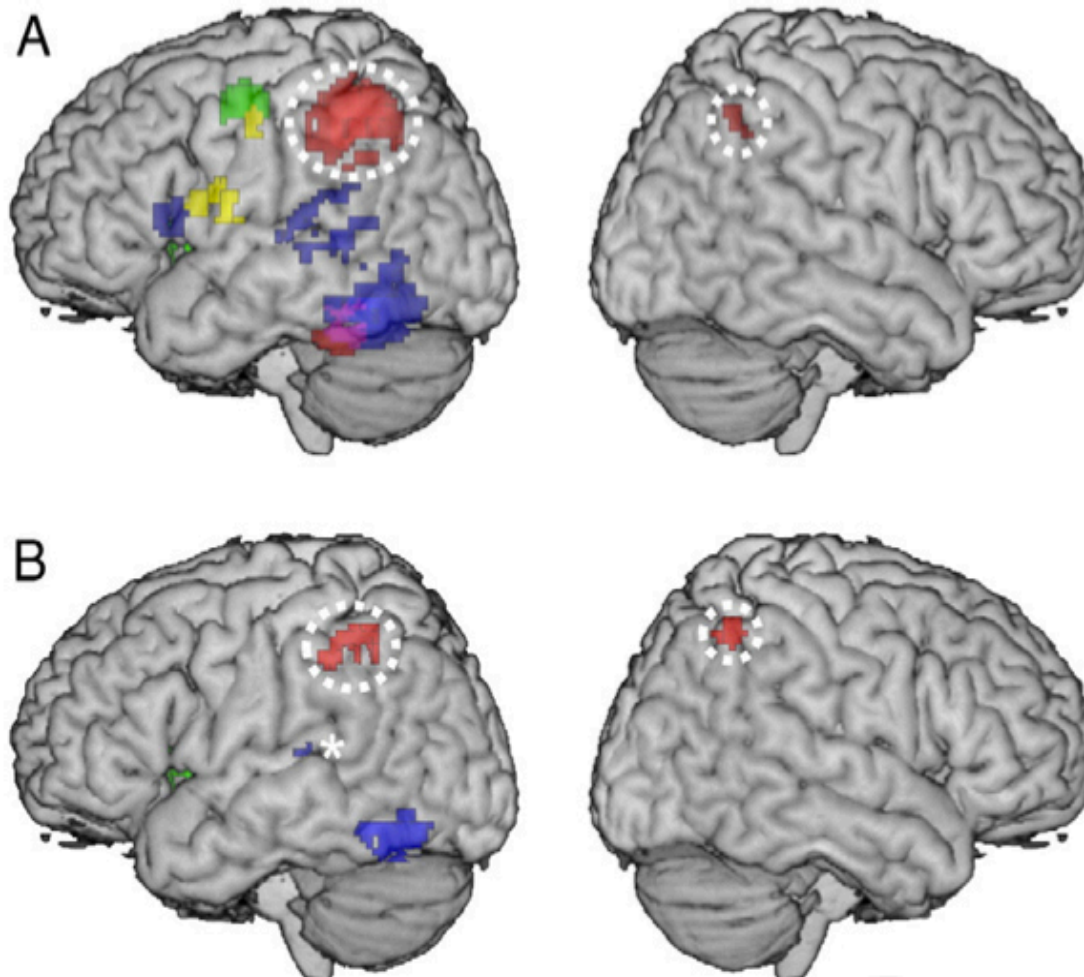
# Meta-analyzing brain dysfunctions in dyslexic children and adults

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- Children underactivation
- Children overactivation
- Adult underactivation
- Adult overactivation



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

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## Abstract

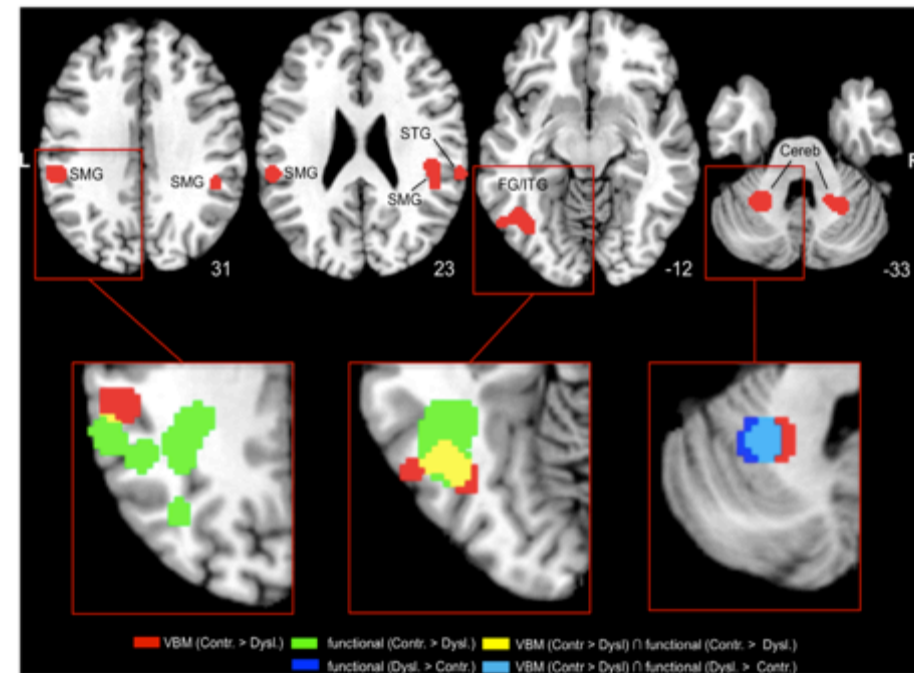
The neural correlates of developmental dyslexia have been investigated intensively over the last two decades and reliable evidence for a dysfunction of left-hemispheric reading systems in dyslexic readers has been found in functional neuroimaging studies. In addition, structural imaging studies using 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 GSM 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 functional overactivations (dark blue). SMG=supramarginal gyrus; STG=superior temporal gyrus; FG/ITG=fusiform gyrus/inferior temporal gyn Cereb=cerebellum.  
doi:10.1371/journal.pone.0043122.g001

## Decreased white-matter density in a left-sided fronto-temporal network in children with developmental language disorder: Evidence for anatomical anomalies in a motor-language network

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<sup>c</sup> Department of Neurology, Johann Wolfgang Goethe-University Frankfurt am Main, Frankfurt, Germany

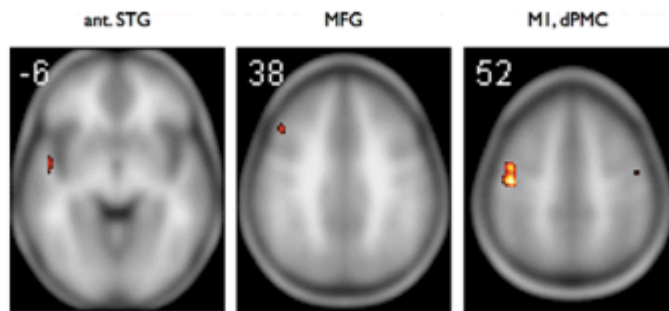


Fig. 2. Areas with decreased white matter (WM) density overlaid on axial slices of the T1-weighted children template. From left to right the three figures show decreased WM density in the anterior part of the superior temporal gyrus (aSTG), the motor cortex (MI) slightly extending into the dorsal premotor cortex (dPMC), and within the middle frontal gyrus region (MFG). There were also two voxels on the right primary motor cortex with decreased WM density. A threshold of  $z = 4.5$  was used.

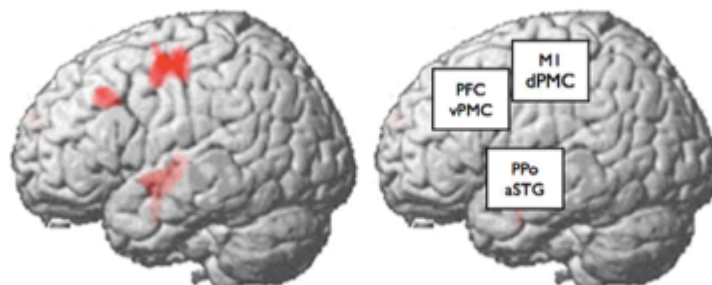


Fig. 3. Areas where children with DLD show decreased relative white matter (WM) volume projected on the surface of the standard MNI template.

21 enfants SLI vs 21  
contrôles normaux IRM +  
VBM, mesure différences  
SB et SG.

Résultats :

« We found decreased WM volumes in a **left-hemispheric network** comprising the motor cortex, the dorsal premotor cortex, the ventral premotor cortex, and the planum polare on the superior temporal gyrus. »



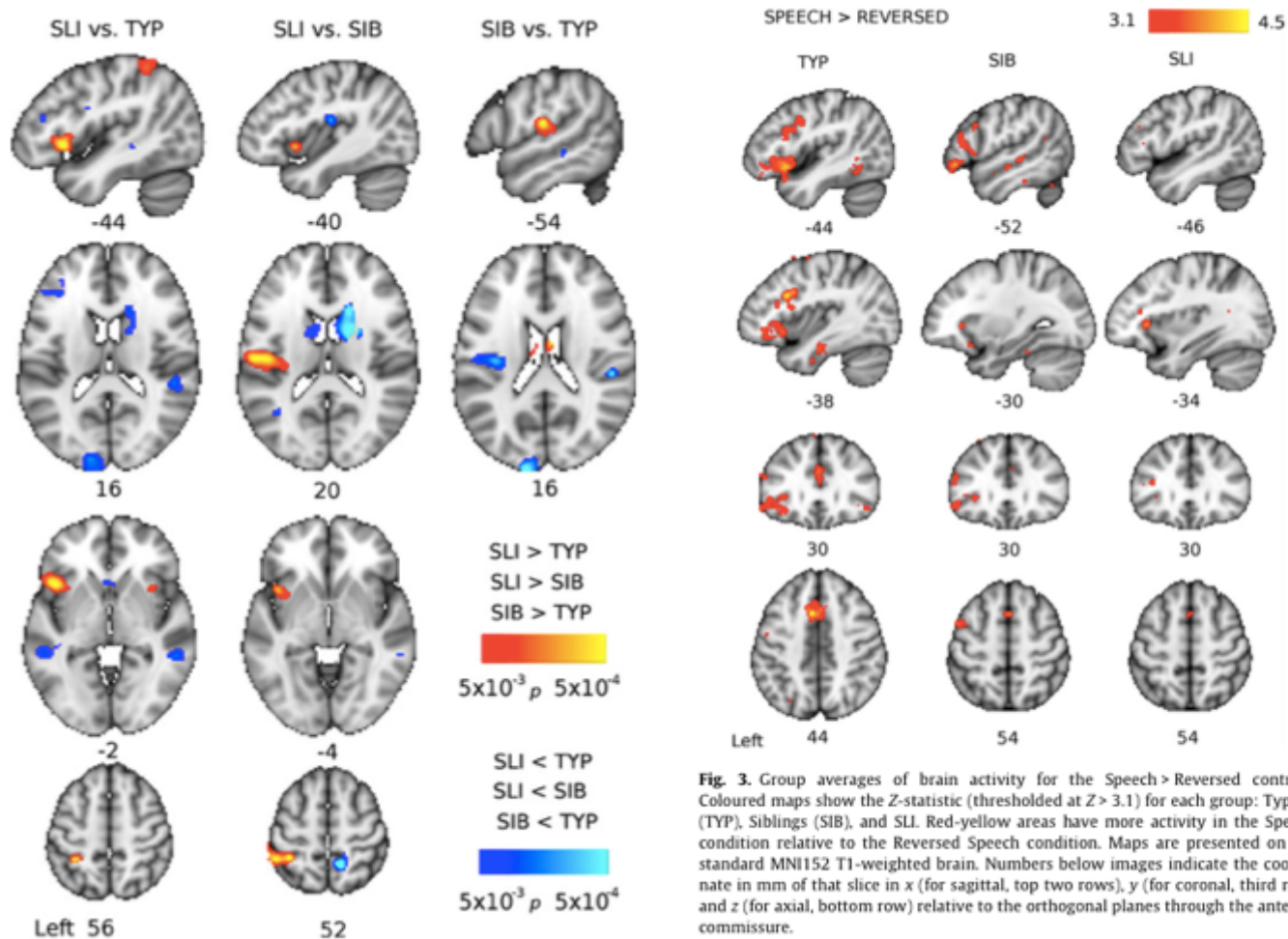


10 sujets SLI 8-17 ans; 6 sujets « siblings »; 16 « unrelated controls ». VBM (imagerie morpho) + fMRI (tâche : ‘wear on head’ -> silently generate ‘hat’)

### Co-localisation of abnormal brain structure and function in specific language impairment

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<sup>a</sup>Department of Experimental Psychology, University of Oxford, South Parks Road Oxford OX1 3UD, United Kingdom



**Fig. 3.** Group averages of brain activity for the Speech > Reversed contrast. Coloured maps show the Z-statistic (thresholded at  $Z > 3.1$ ) for each group: Typical (TYP), Siblings (SIB), and SLI. Red-yellow areas have more activity in the Speech condition relative to the Reversed Speech condition. Maps are presented on the standard MNI152 T1-weighted brain. Numbers below images indicate the coordinate in mm of that slice in x (for sagittal, top two rows), y (for coronal, third row) and z (for axial, bottom row) relative to the orthogonal planes through the anterior commissure.

VBM SLI vs cont :  
 ↑ left inferior frontal cortex ↓  
 in the right caudate nucleus and superior temporal cortex bilaterally.  
 SIB : ↓ caudate nucleus relative to controls.

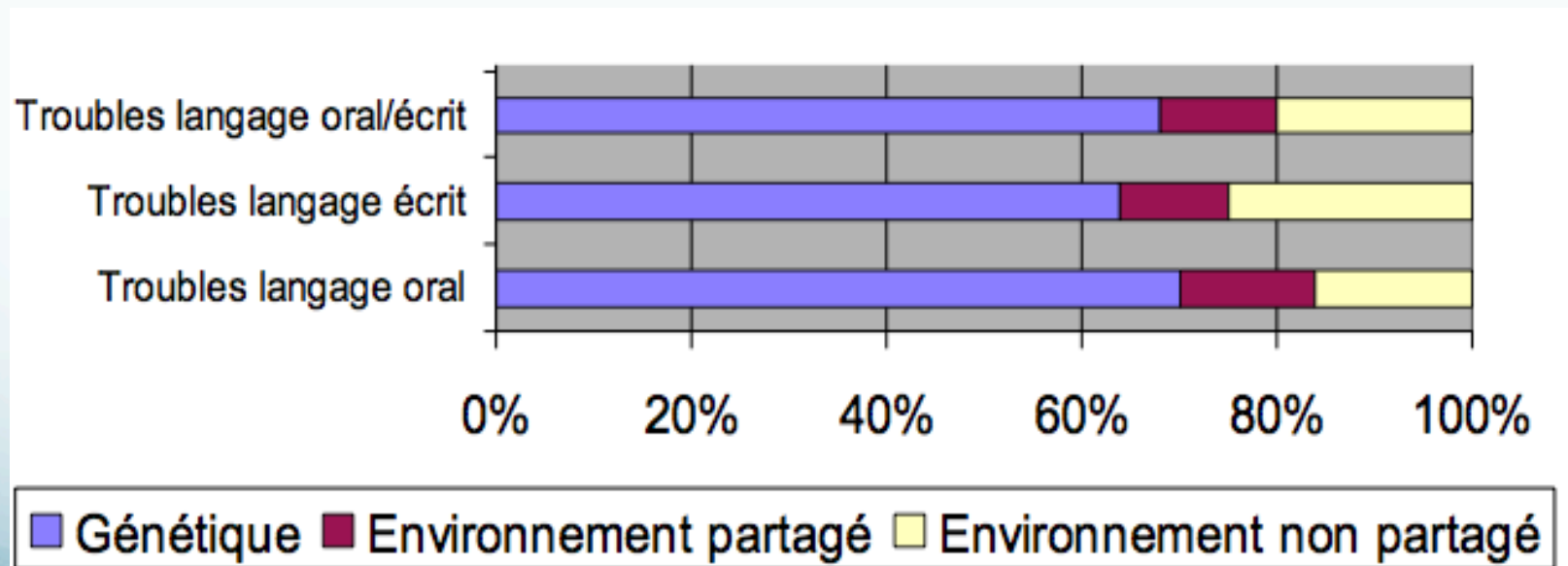
IRMf : ↓  
 activation left inferior frontal cortex, right putamen, and in the superior temporal cortex bilaterally.

Support de cours :  
[www.resodys.org](http://www.resodys.org)  
(dès mercredi matin)

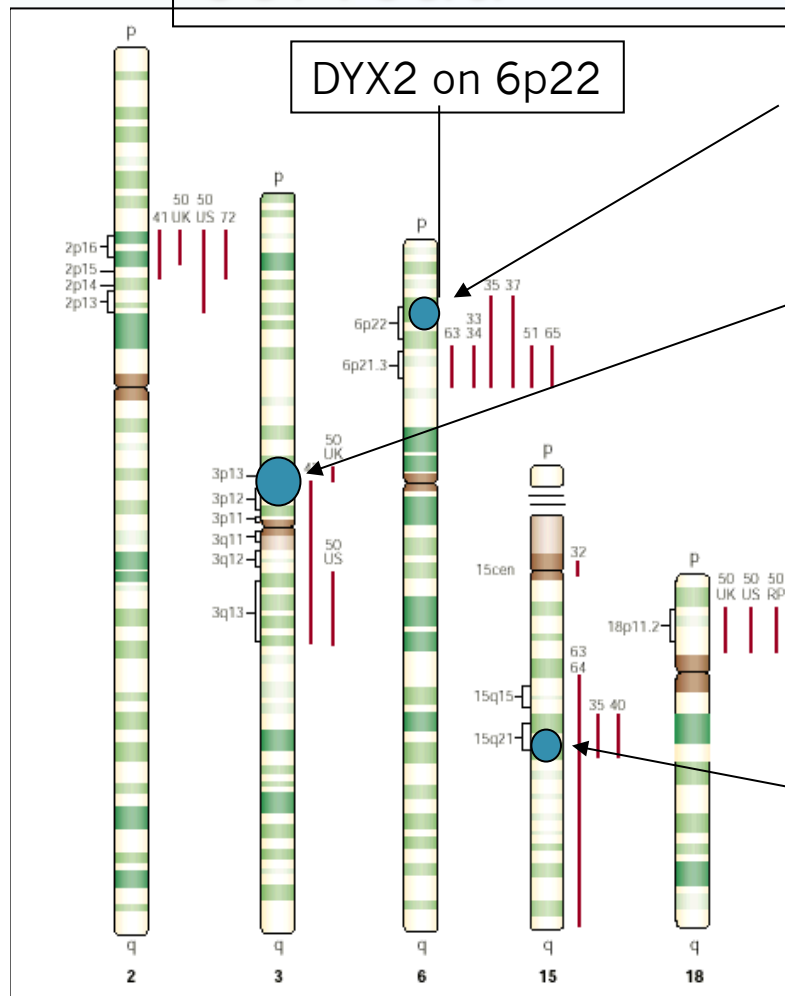
# Origine génétique possible

- Dyslexie 8 fois plus fréquente chez les enfants dont les parents ont une histoire de difficultés de lecture
- 25-60% des parents de dyslexiques ont également des difficultés de lecture
- Etude de jumeaux : taux de concordance : 68% pour monozygotes / 38% pour dizygotes.
- Liens entre dyslexie et marqueurs sur les chromosomes 6 (bras court; Grigorenko et al., 1997), 15 (bras long; Smith et al., 1983) et 18.

# Héritabilité des troubles du langage oral et écrit (Stromswold, 2001)



# Plusieurs gènes identifiés par les analyses de liaisons ont également un rôle connu dans le développement du cerveau

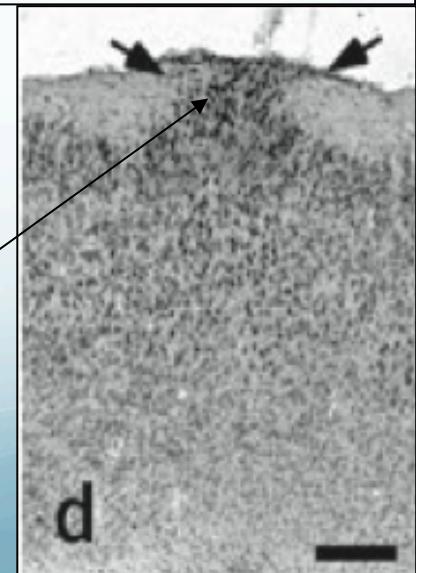


DYX2 on 6p22

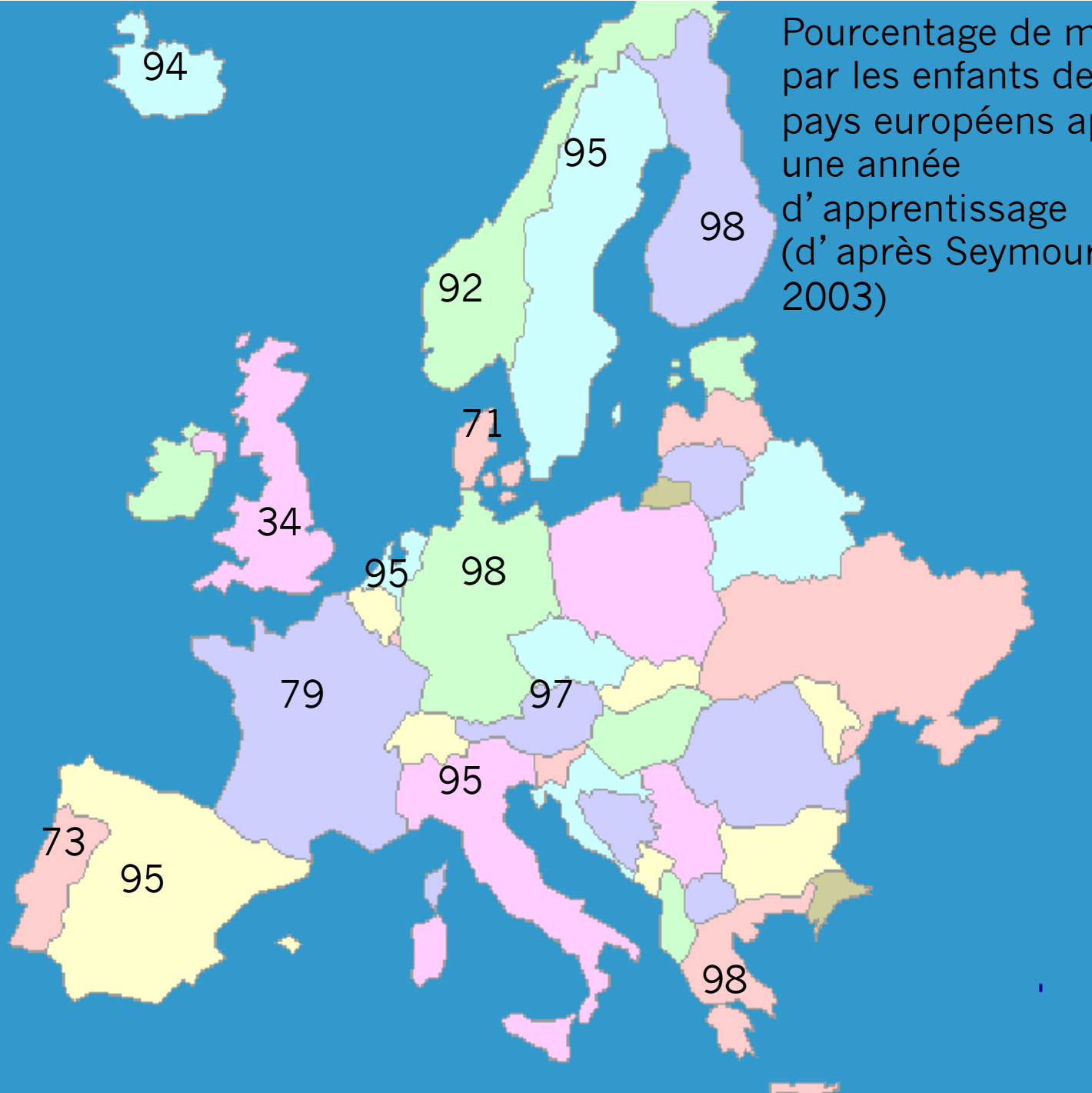
DCDC2 : un gène associé chez l'animal et chez l'homme à une migration neuronale anormale

ROBO1 : joue un rôle dans la régulation du passage de la ligne médiane par les axones calleux

Une manipulation in utero de DYX1C1 provoque des ectopies similaires à celles des humains dyslexiques

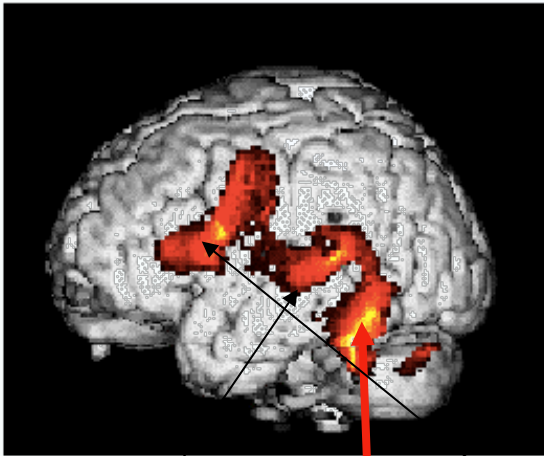


Pourcentage de mots lus  
par les enfants de 14  
pays européens après  
une année  
d'apprentissage  
(d'après Seymour et al.,  
2003)





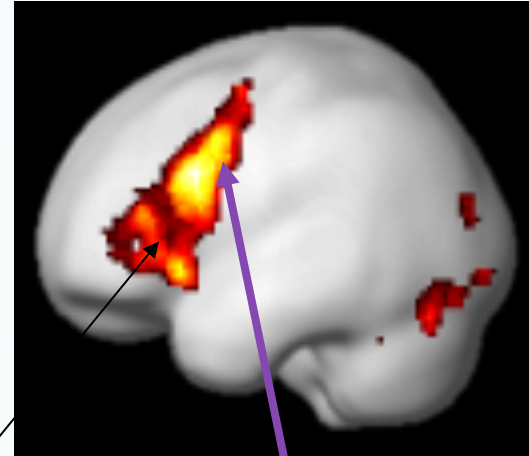
A



Wernicke's area

**Posterior temporal lobe (VWFA)**

B



电  
+  
店

Broca's area (BA45)

**Middle frontal gyrus (BA9)**

Siok et al., (2004)

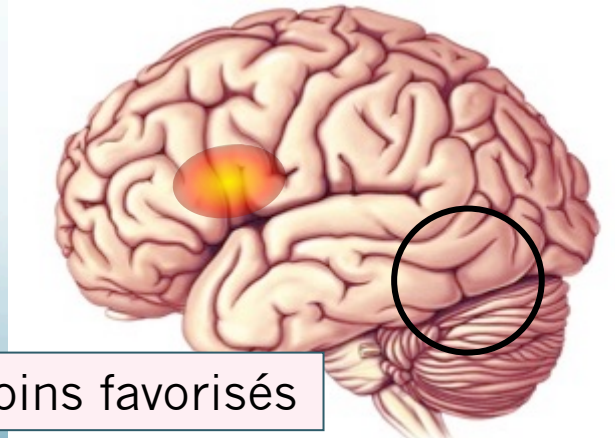
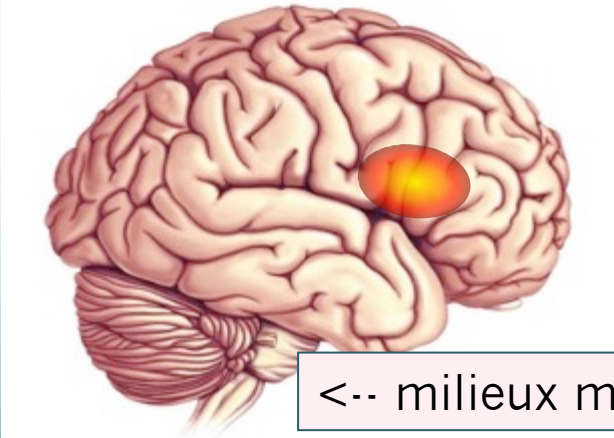
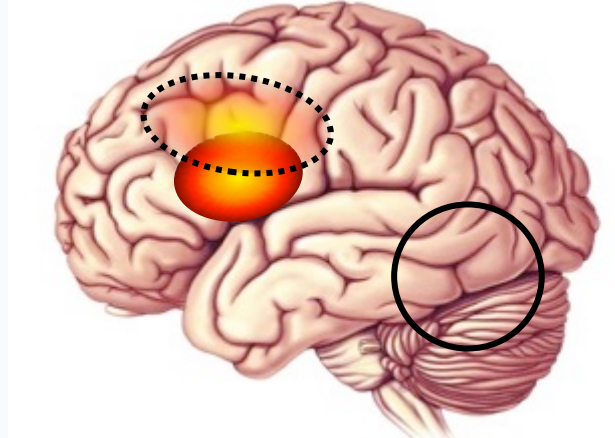
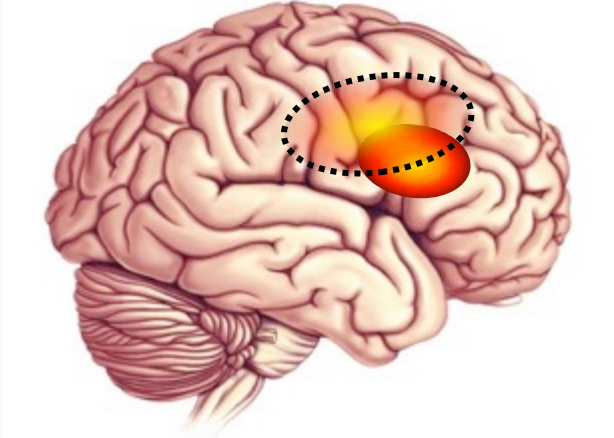
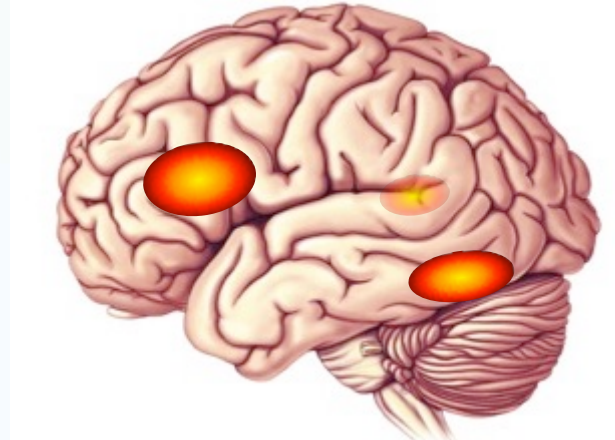
LEAT JETE

Témoins non dys

Riment?

Dyslexiques "compensés"

Dyslexiques "persistants"



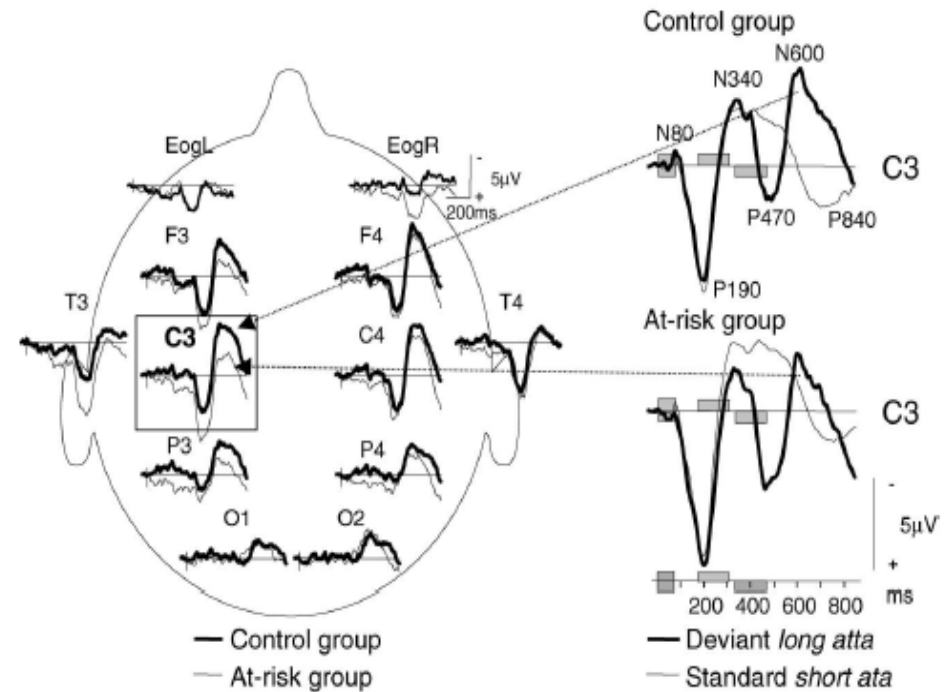
<- milieu moins favorisés



## Brain Responses to Changes in Speech Sound Durations Differ Between Infants With and Without Familial Risk for Dyslexia

Paavo H. T. Leppänen  
*Department of Psychology  
University of Jyväskylä*

Ulla Richardson

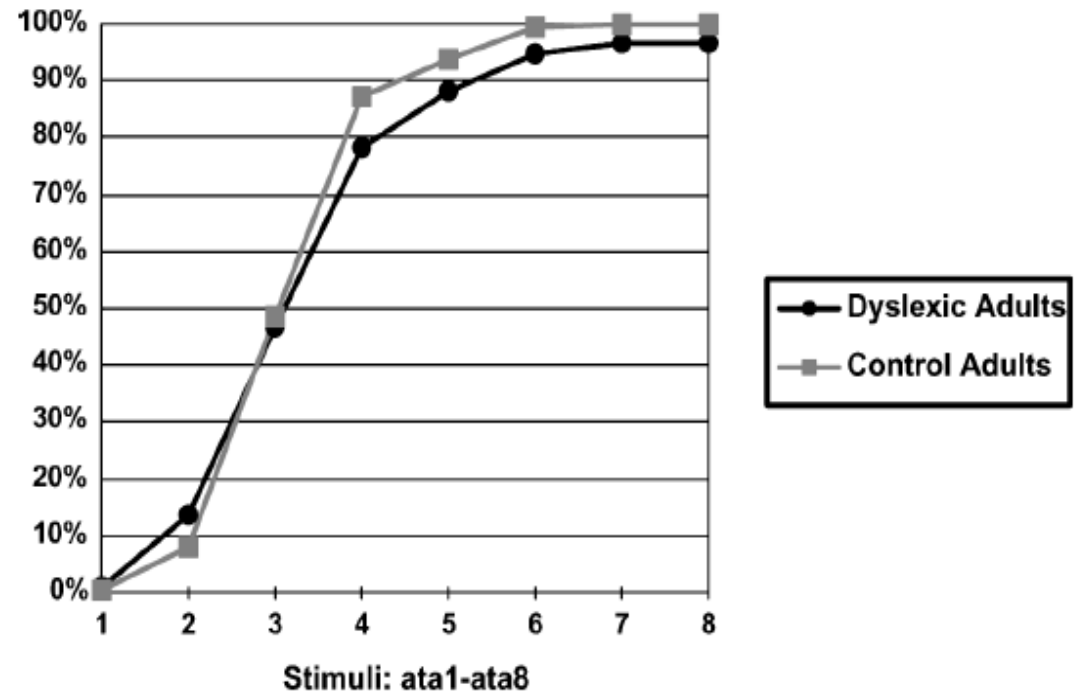
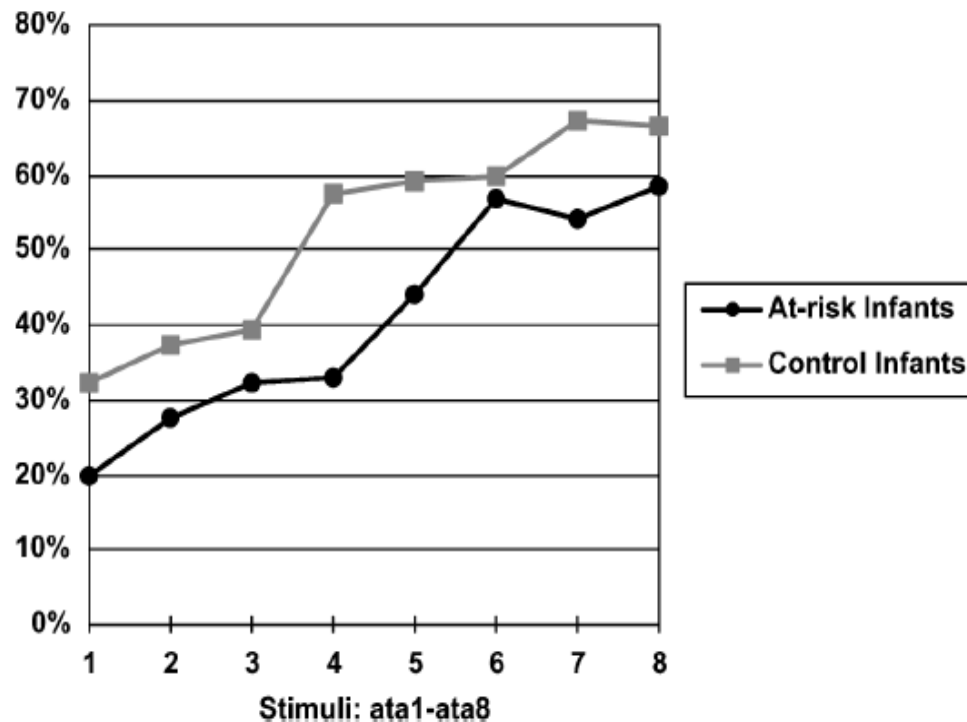


Enfants de 6 mois à risque familial de dyslexie : défaut d'activation cérébrale par un stimulus déviant quant à ses caractéristiques temporelles (/ata/ vs /atta/)

## Speech Perception of Infants With High Familial Risk for Dyslexia Differ at the Age of 6 Months

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*Faculty of Education  
University of Cambridge, United Kingdom*

Paavo H. T. Leppänen  
*Department of Psychology*



Enfants de 6 mois : perception catégorielle - groupe à risque familial de dyslexie  
Méthode d'orientation de la tête  
Différence significative sur l'item 4  
Même item chez des dyslexiques adultes

# Infant brain responses associated with reading-related skills before school and at school age<sup>☆</sup>

*Les potentiels liés à l'événement (ERPs) chez le nouveau-né et le nourrisson permettent de prévoir les compétences en lecture en âge préscolaire et scolaire*

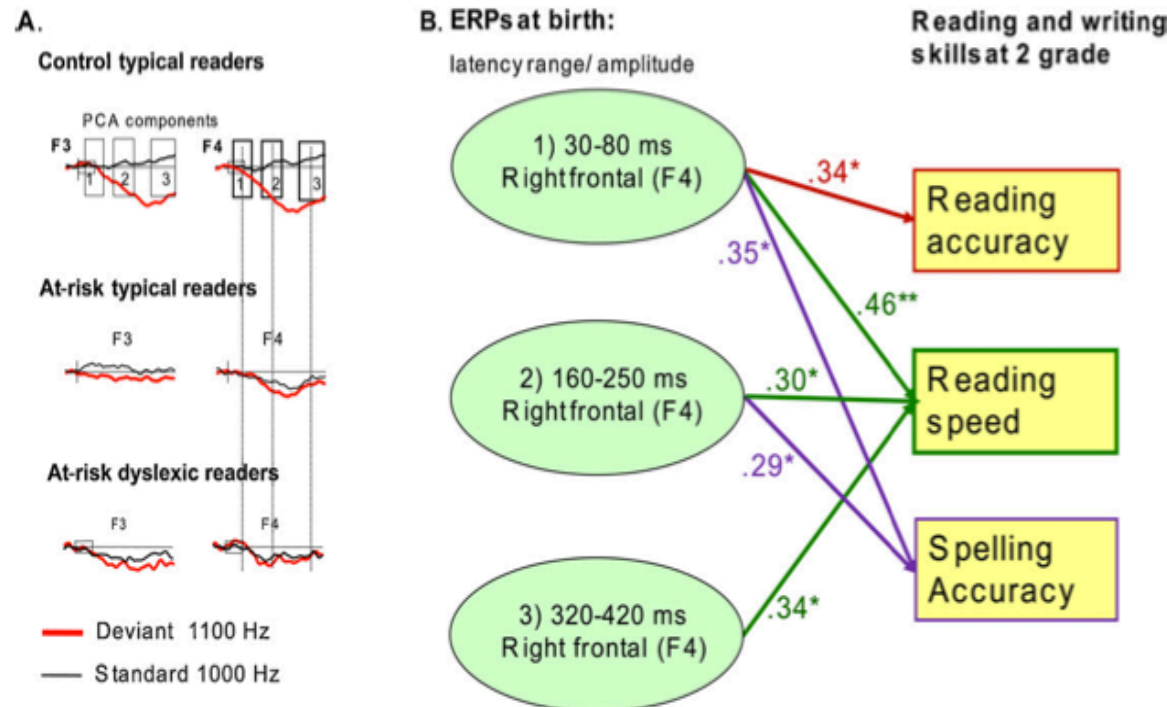
P.H.T. Leppänen\*, J.A. Hämäläinen, T.K. Guttorm, K.M. Eklund, H. Salminen, A. Tanskanen, M. Torppa, A. Puolakanaho, U. Richardson, R. Pennala, H. Lyytinen

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*Patients et méthodes.* ERP à la naissance, à 6 mois et en "grade 2" La moitié des enfants venaient de familles dont au moins un des parents était dyslexique (groupe à risque), l'autre moitié (groupe témoin) n'avaient aucun antécédent familial de dyslexie. *Résultats.* Les ERPs précoces étaient corrélés aux traitements phonologiques en âge préscolaire, aux capacités de dénomination de lettres et de perception de la durée des phonèmes ainsi qu'aux performances de lecture et d'écriture en âge scolaire. Ces corrélations étaient généralement plus fortes chez les enfants à risque.

Infant brain responses are associated with reading-related skills



also the at-risk children with later typical reading skills showed differences already in their responses to the pitch change at birth as compared to the control group typical readers. The smaller responses in both of the at-risk groups compared to the control group could suggest a genetically driven difference in the auditory system of at least a subgroup of at-risk children.

# ■ Precursors of Developmental Dyslexia: An Overview of the Longitudinal Dutch Dyslexia Programme Study

Aryan van der Leij<sup>1\*</sup>, Elsje van Bergen<sup>1,2</sup>, Titia van Zuijlen<sup>1</sup>, Peter de Jong<sup>1</sup>,  
Natasha Maurits<sup>3</sup> and Ben Maassen<sup>4</sup>

<sup>1</sup>Research Institute of Child Development and Education, University of Amsterdam, Amsterdam, The Netherlands

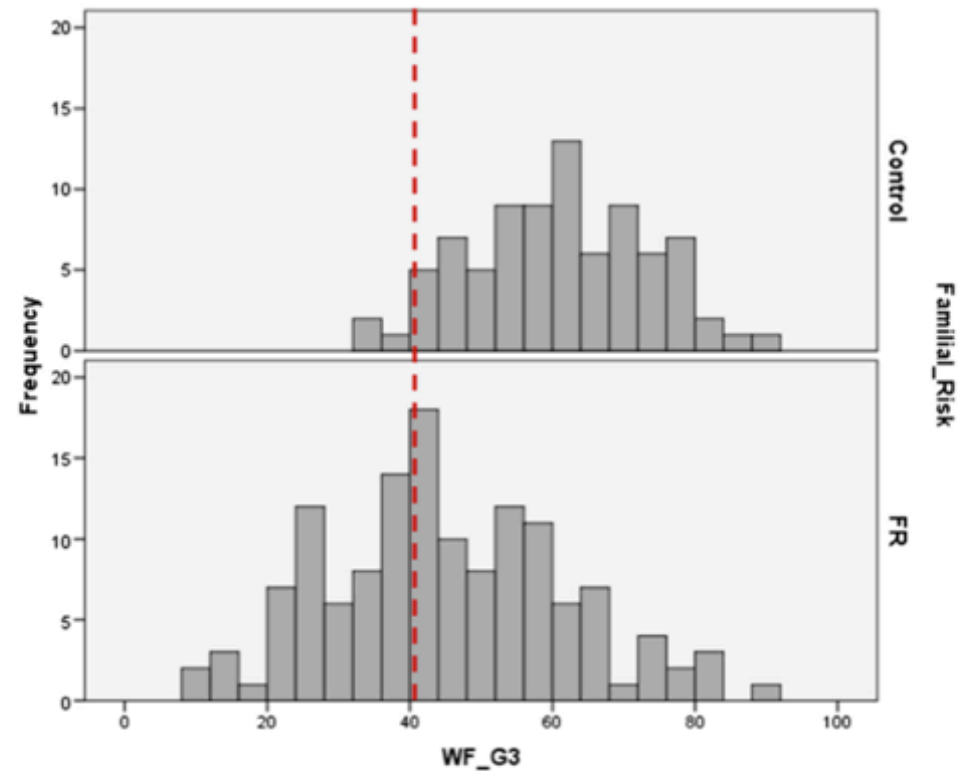


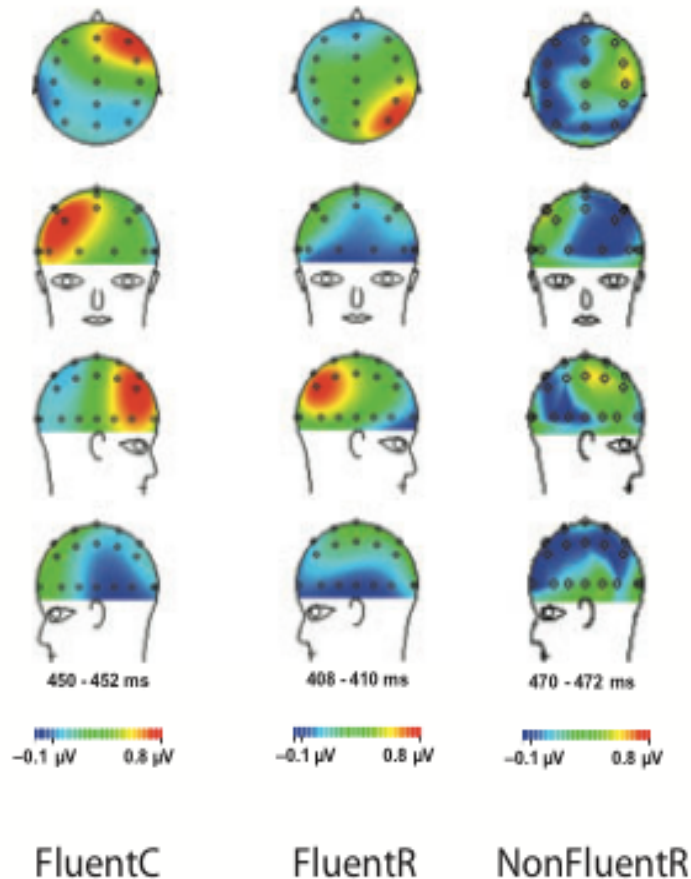
Figure 1. The distribution of word reading fluency in Grade 3 (WF\_G3) for the children with and without familial risk; red vertical dotted line indicates the bottom 10% on national norms.

PAPER

Infant ERPs separate children at risk of dyslexia who become good readers from those who become poor readers

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*1. Department of Child Development and Education, Faculty of Social and Behavioral Sciences, University of Amsterdam, The Netherlands*



26 healthy 2-month-old infants (17 boys) with a familial risk of dyslexia and 12 healthy controls (eight boys).

In October in grade two, when the children had an average age of 7 years and 4 month (SD 4.2 months), word reading fluency scores were measured

*« In infants who became fluent readers (both the control infants and part of the at-risk infants) an MMR was elicited at the age of 2 months, showing that their auditory system processed the standard stimulus /bAk/ differently from the deviant stimulus /dAk/. We did not find evidence for such discriminative processing in the infants who later on became non-fluent readers (39% of the at-risk infants) »*





## 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

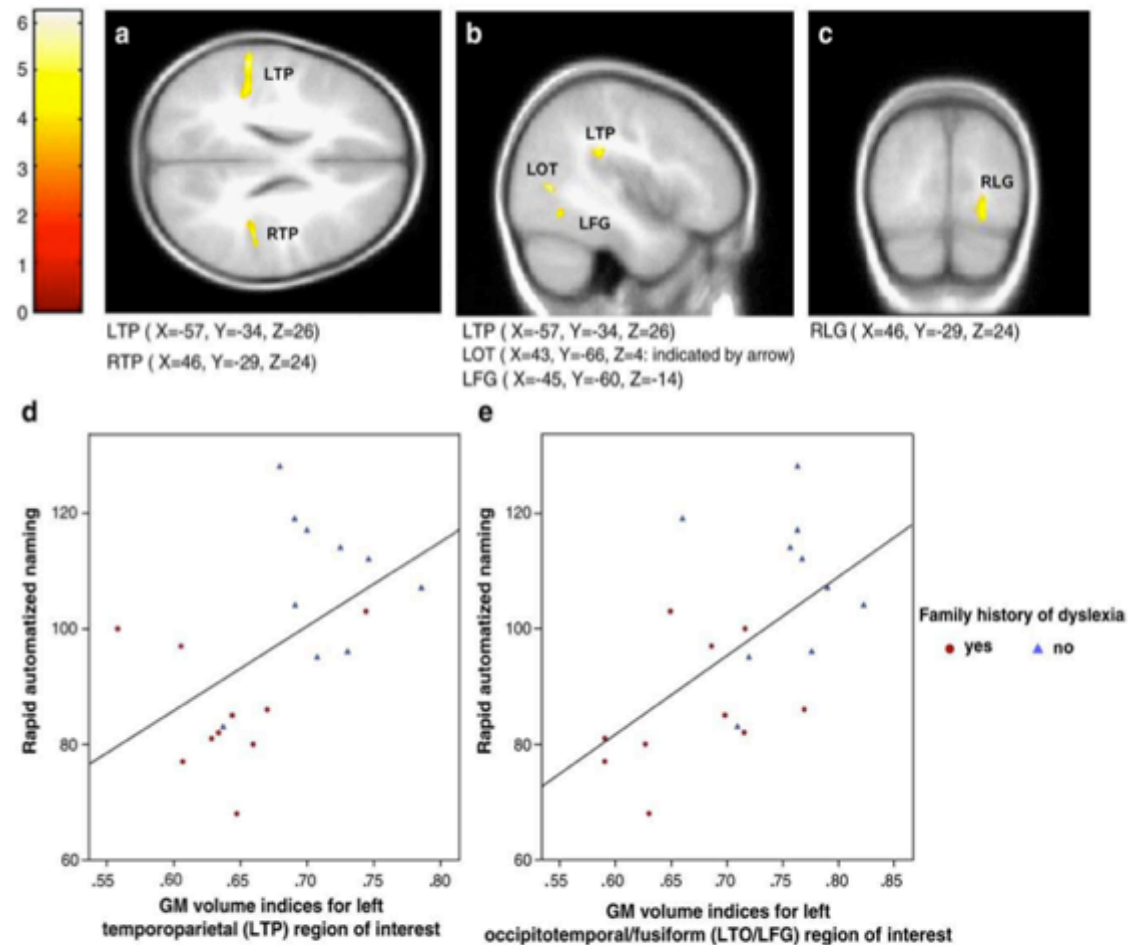


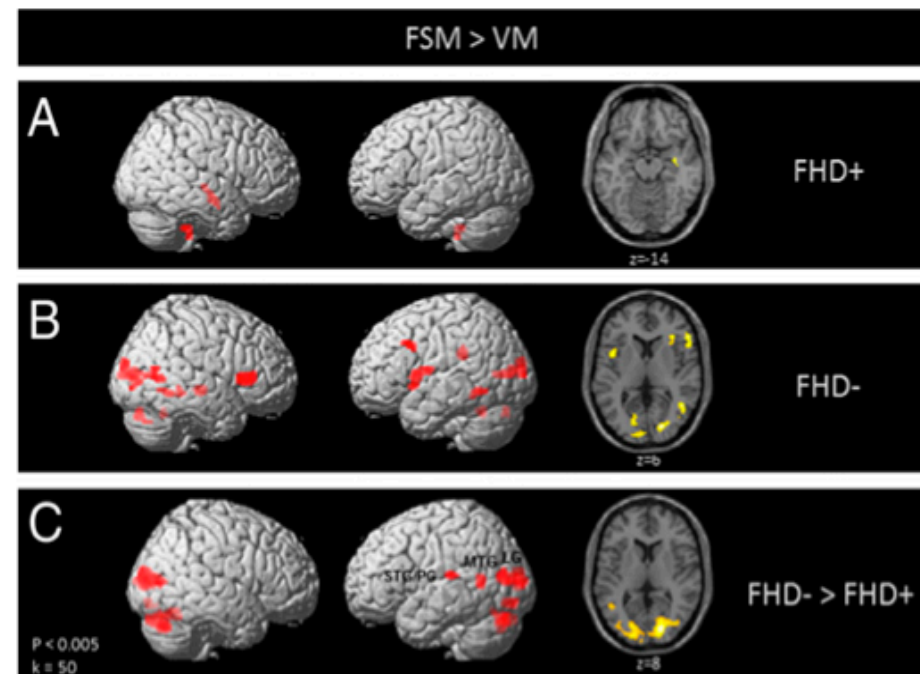
Fig. 1. [a-c] Statistical parametric maps showing brain areas with significant decreased gray matter volume indices in pre-reading FHD+ compared to FHD- children (a = axial, b = sagittal, c = coronal view). [d-e] Correlations between gray matter volume indices in the left parietotemporal (d) and left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

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

Nora Maria Raschle<sup>a,b</sup>, Jennifer Zuk<sup>a</sup>, and Nadine Gaab<sup>a,b,c,1</sup>

<sup>a</sup>Laboratories of Cognitive Neuroscience, Division of Developmental Medicine, Department of Medicine, Children's Hospital Boston, and <sup>b</sup>Harvard Medical School, Boston, MA 02115; and <sup>c</sup>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



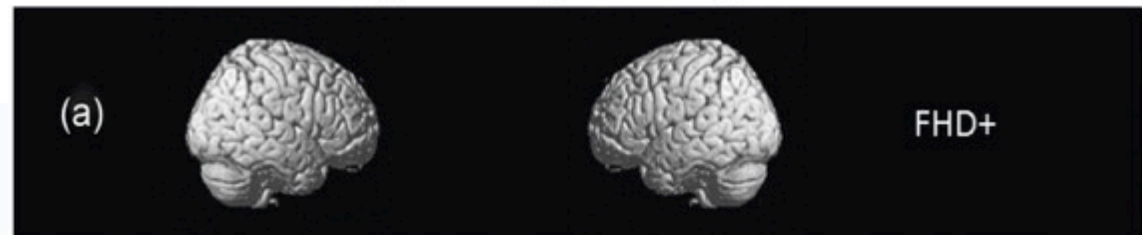
**Fig. 1.** Statistical parametric maps showing brain activation during phonological processing (FSM > VM) for children with (A) and without (B) a familial risk for DD, as well as group differences between children with compared to without (FHD<sup>-</sup> > FHD<sup>+</sup>) a familial risk for DD (C).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

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

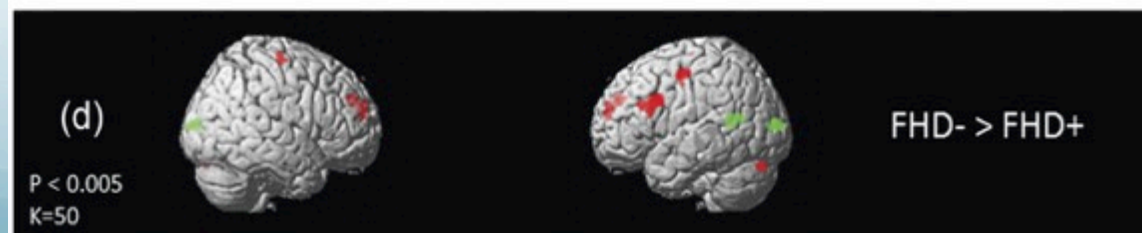
Nora M. Raschle<sup>1,2</sup>, Patrice L. Stering<sup>1</sup>, Sarah N. Meissner<sup>1</sup> and Nadine Gaab<sup>1,2,3</sup>

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

### Rapid Auditory Processing



### Rapid Auditory & Phonological Processing





## REPORT

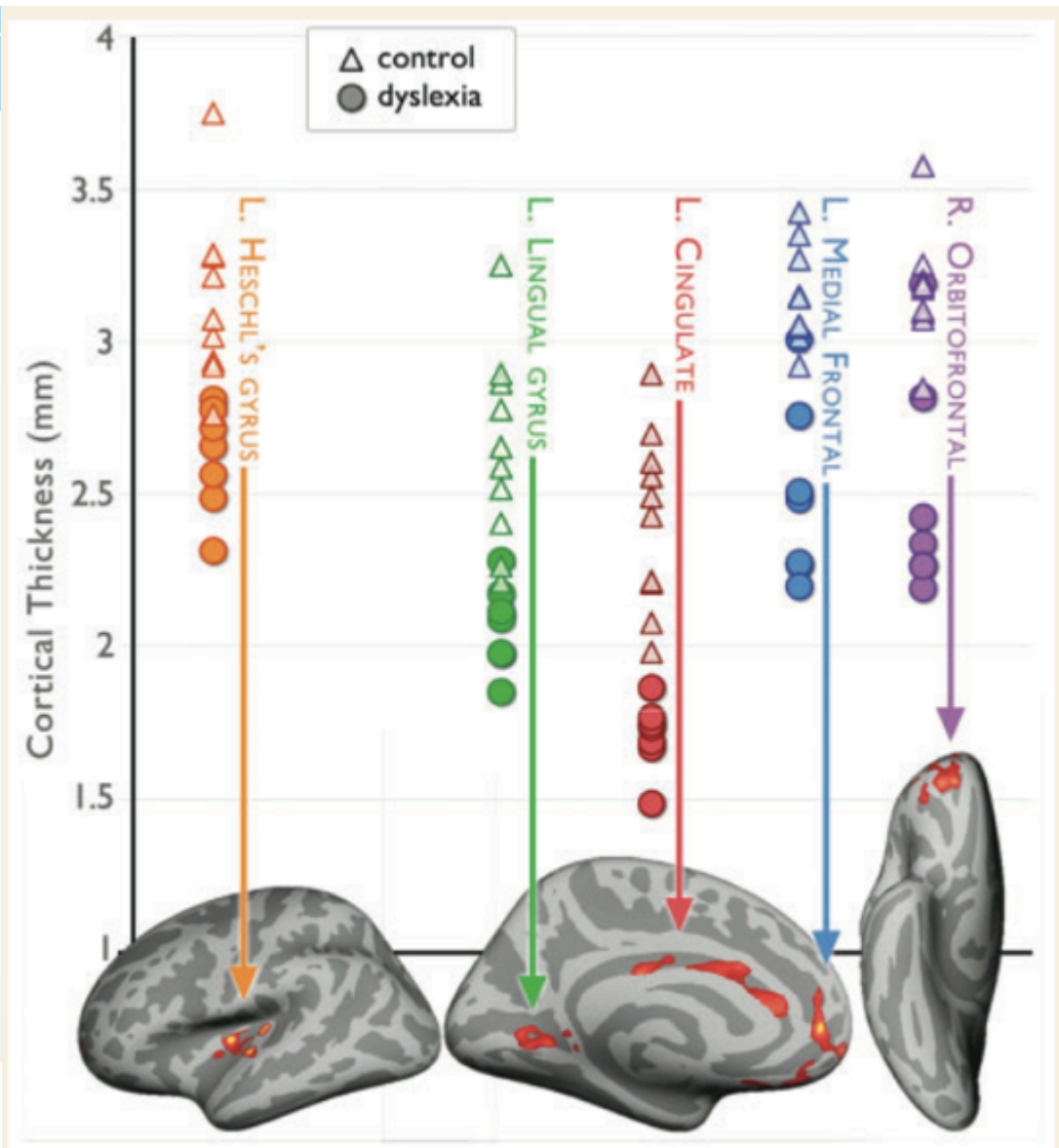
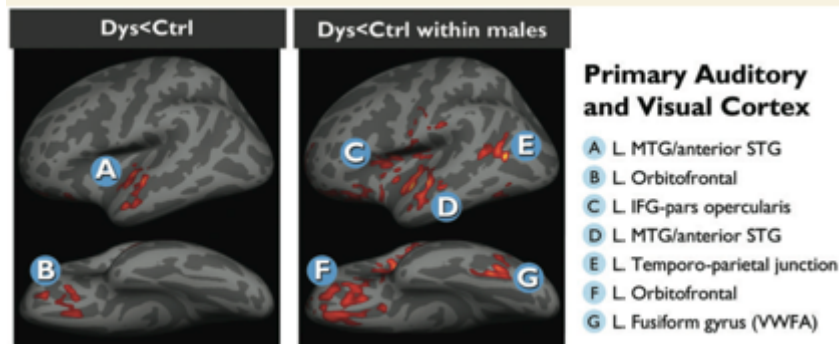
## Neuroanatomical precursors of dyslexia identified from pre-reading through to age 11

 Kristi A. Clark,<sup>1</sup> Turid Helland,<sup>2,3</sup> Karsten Specht,<sup>2,4</sup> Katherine L. Narr,<sup>5,6</sup> Franklin R. Manis,<sup>7</sup> Arthur W. Toga<sup>1</sup> and Kenneth Hugdahl<sup>2,8,9</sup>
<sup>1</sup> Laboratory of Neuro Imaging and Institute for Neuroimaging and Informatics, Department of Neurology, Keck School of Medicine of University of Southern California, Los Angeles, CA, 90032, USA

<sup>2</sup> Department of Biological and Medical Psychology, University of Bergen, 5009 Bergen, Norway

Longitudinal MRI study : MRI scans were acquired in the spring of 3 years: first grade (MRI 1, ages 6–7), third grade (MRI 2, ages 8–9), and sixth grade (MRI 3, ages 11–12).

we were able to determine that the primary neuroanatomical abnormalities that precede dyslexia **are not in the reading network** itself, but rather **in lower-level areas responsible for auditory and visual processing** and core executive functions. Abnormalities in the reading network itself were **only observed at age 11**, after children had learned how to read.



**Figure 1** Early signs of dyslexia. Pre-reading differences in cortical thickness between children who later went on to develop dyslexia (Dys) and those who did not (Ctrl). Images: regions in which Dys < Ctrl before the onset of reading. Raw

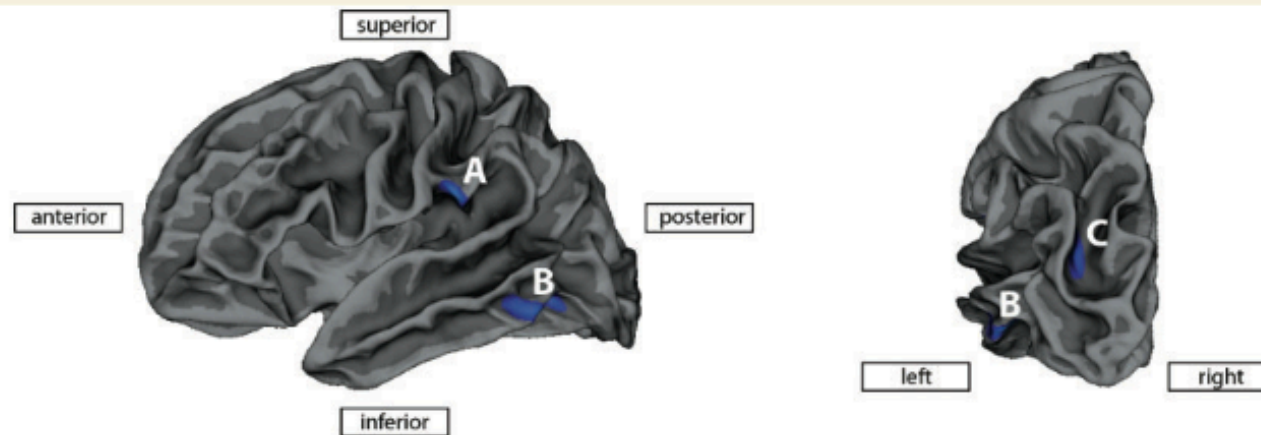
## LETTER TO THE EDITOR

### Cortical differences in preliterate children at familiar risk of dyslexia are similar to those observed in dyslexic readers

Indra Kraft,<sup>1</sup> Riccardo Cafiero,<sup>1</sup> Gesa Schaadt,<sup>1,2</sup> Jens Brauer,<sup>1</sup> Nicole E. Neef,<sup>1</sup> Bent Müller,<sup>3</sup> Holger Kirsten,<sup>3</sup> Arndt Wilcke,<sup>3</sup> Johannes Boltze,<sup>3,4</sup> Angela D. Friederici<sup>1</sup> and Michael A. Skeide<sup>1</sup>

<sup>1</sup> Department of Neuropsychology, Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany

Crucially, Clark and colleagues had only 57% power in their sample at MRI time point 1 to detect the clusters in the left supramarginal gyrus and the left occipito-temporal cortex identified in our analyses (effect size = 0.93; effect size in Clark et al. = 0.53; effect size is defined as the mean difference divided by common standard deviation). Despite the significant value of the longitudinal study by Clark and colleagues for the field, larger and statistically more powerful studies may be required to reveal ultimately which of the contrary hypotheses best approximates reality.



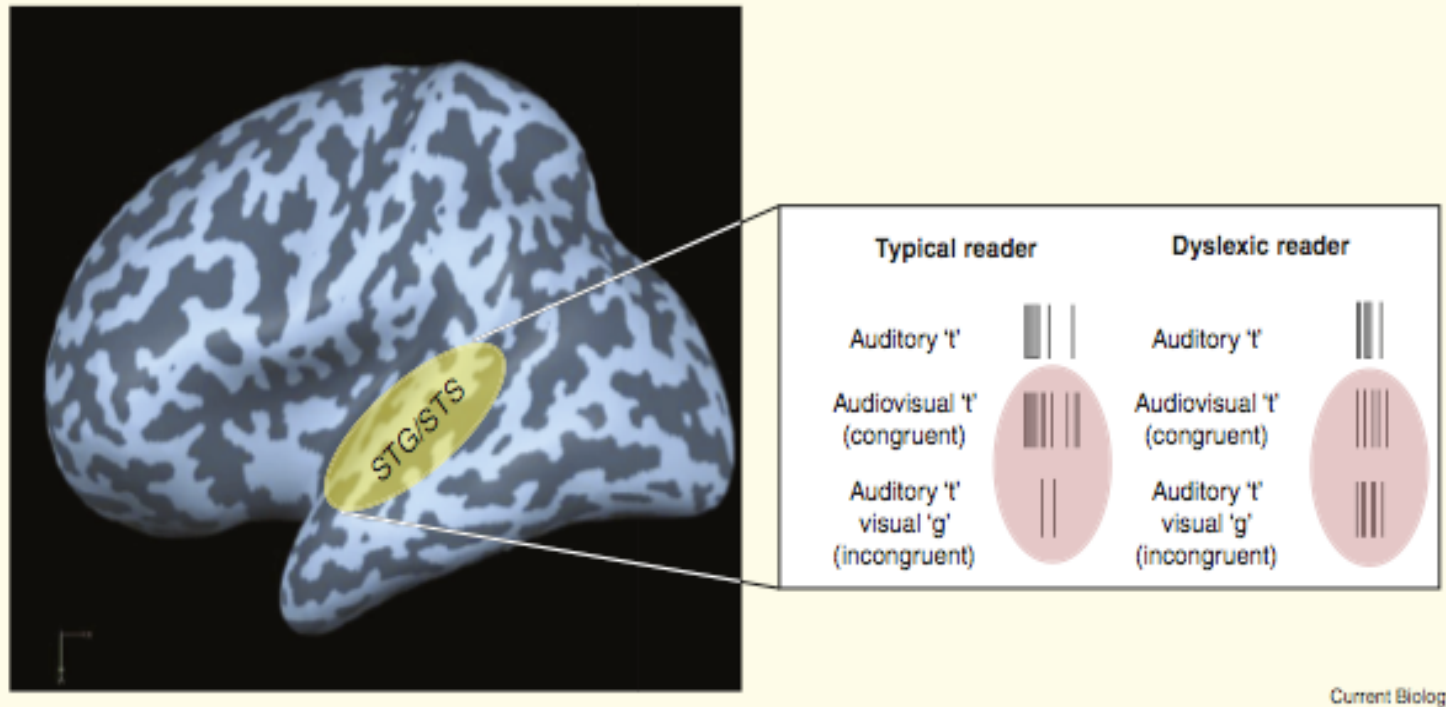
**Figure 1** Cortical thickness differences between 5-year-old preliterate children at familial risk of developmental dyslexia and non-risk controls. Compared to children without a family history of developmental dyslexia, individuals with a family history of developmental dyslexia showed a significantly reduced cortical thickness ( $P < 0.05$ , false discovery rate corrected) in the left supramarginal gyrus (**A**), the left inferior temporal gyrus (**B**), and the left superior and transversal occipital sulci (**C**), but not in right-hemispheric regions. The opposite contrast (non-risk children versus at-risk children) did not reveal any significant results. Depicted are z-transformed cortical thickness values on the white matter surface of the group-averaged left hemisphere.

Dysconnectivité inter-modalitaire : une explication unitaire des troubles dys?



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/).





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



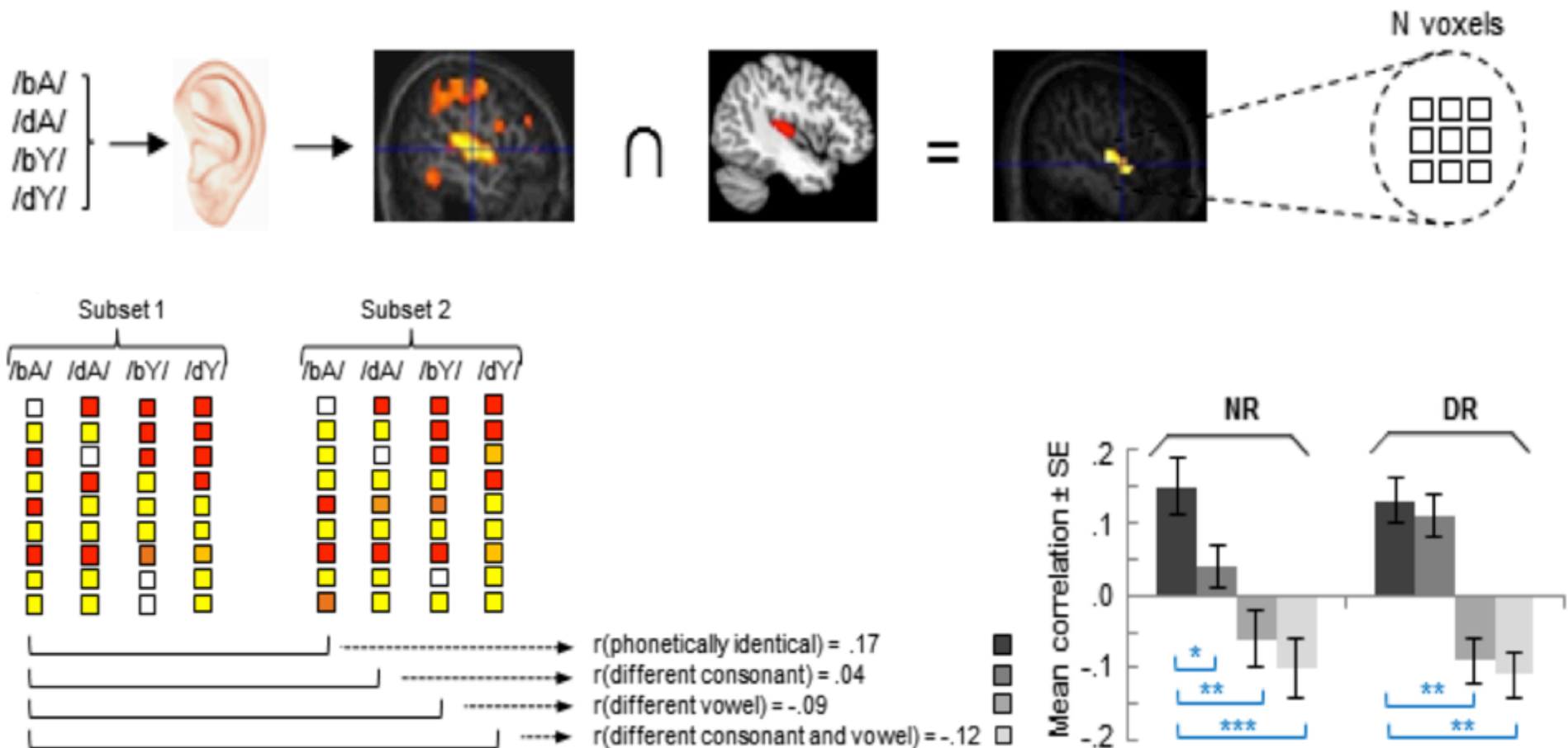


# Intact But Less Accessible Phonetic Representations in Adults with Dyslexia

Bart Boets *et al.*

*Science* **342**, 1251 (2013);

DOI: 10.1126/science.1244333

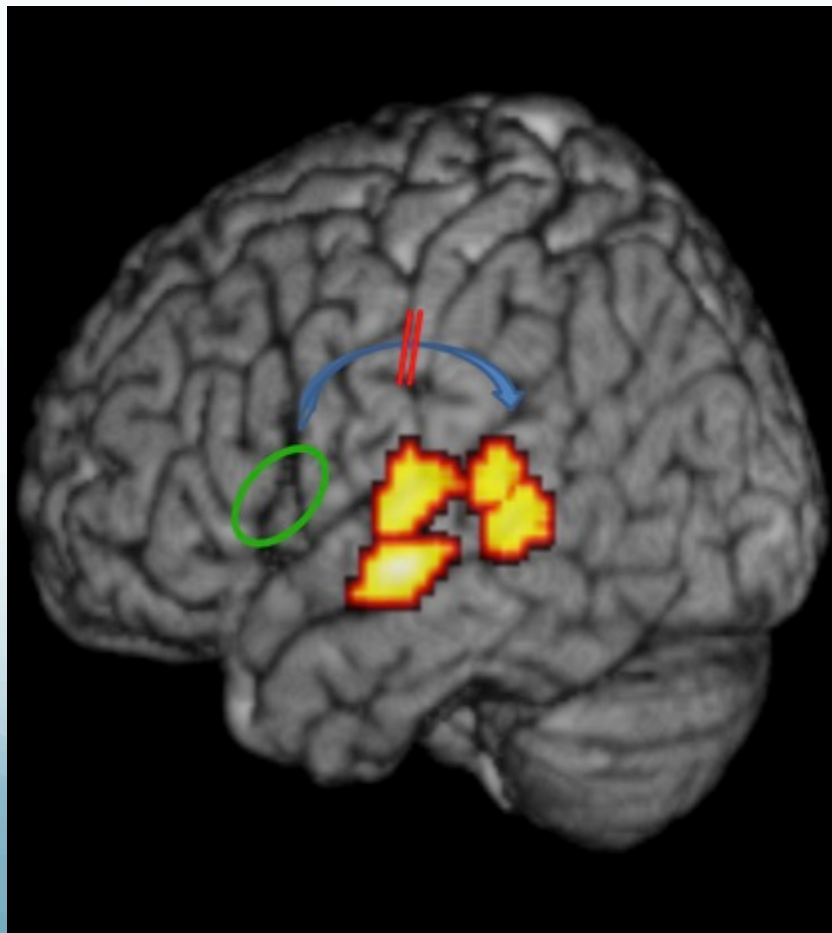


## Boets et al. : conclusions

- les corrélations sont plus fortes au sein d'une catégorie qu'entre les catégories : signe la robustesse des représentations

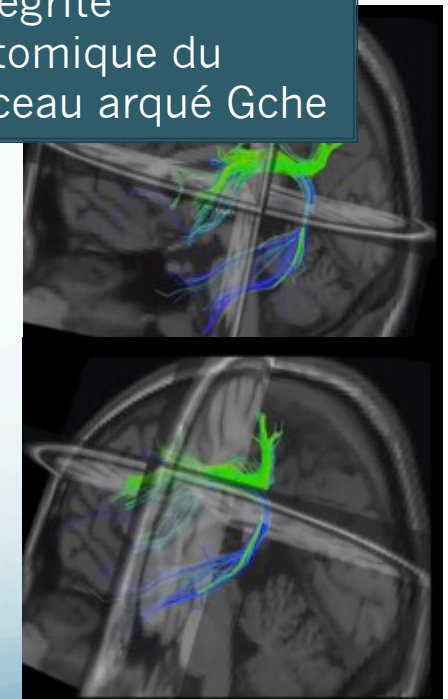
- les représentations sont aussi robustes chez les DYS que chez les NL : représentations ne sont pas altérées/dégradées chez les DYS

→ Les DYS auraient un problème **d'accès à des représentations intactes**

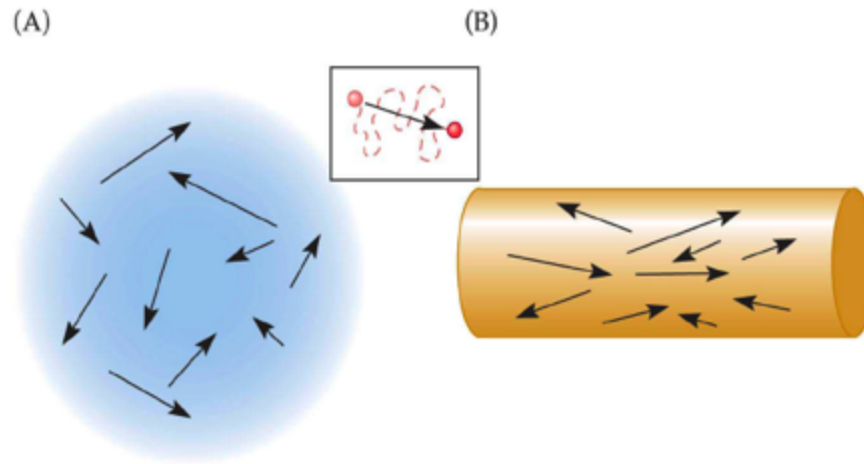


Défaut de connectivité fonctionnelle entre Broca et aires auditives D/G

Réduction de l'intégrité anatomique du faisceau arqué Gche

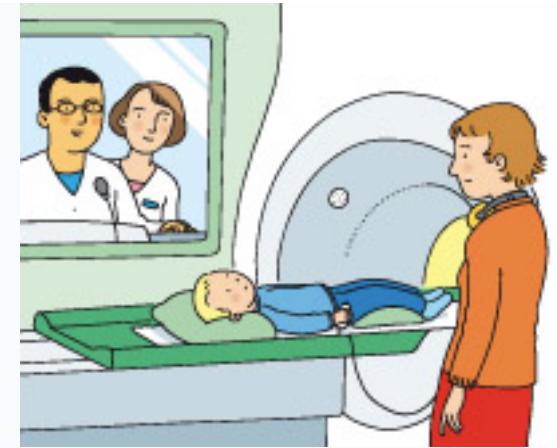


5.18 Isotropic and anisotropic diffusion.

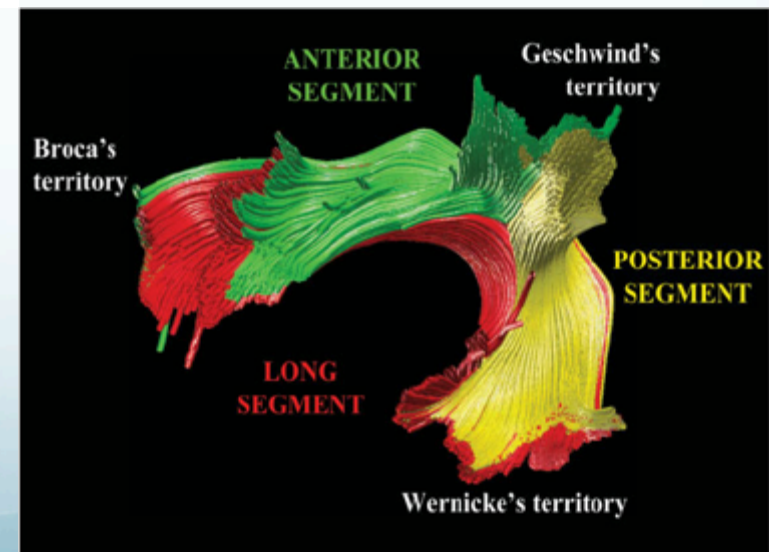


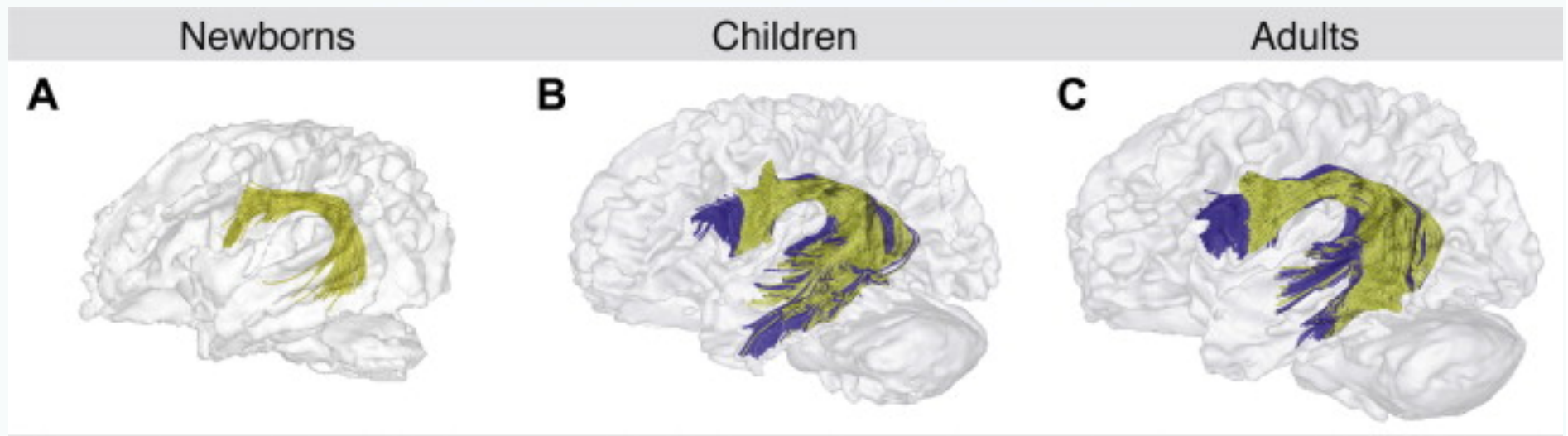
Diffusion tensor imaging (D.T.I.)

FUNCTIONAL MAGNETIC RESONANCE IMAGING Figure 5.18 © 2004 Elsevier Associates, Inc.



Le faisceau arqué : principal marqueur anatomique de la dyslexie

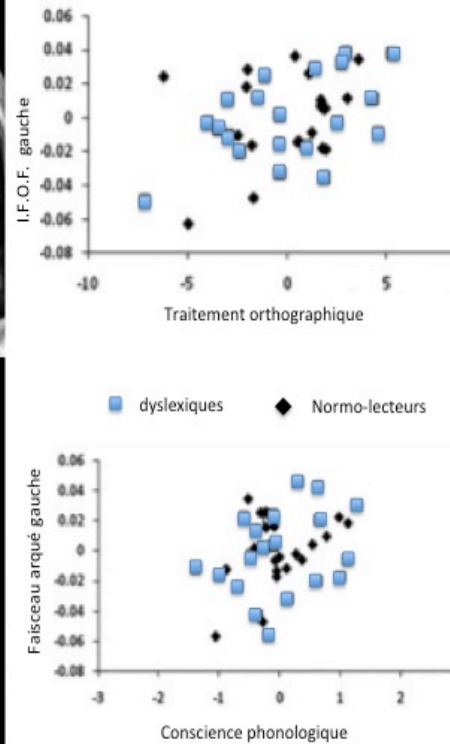
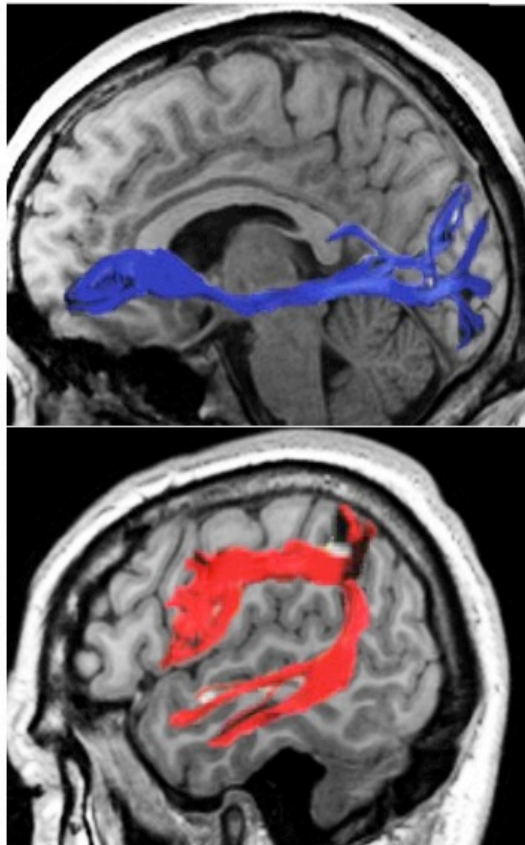




Le faisceau arqué, qui connecte les aires de Broca et de Wernicke est constitué de deux contingents : l'un ventral, présent dès la naissance, qui serait responsable du développement linguistique initial (fonctionnerait comme un extracteur de règles d'invariance dans la phonologie et la syntaxe). L'autre dorsal, n'apparaissant que vers 7ans, responsable de fonctions linguistiques plus complexes (sous l'influence de la lecture?).

[Brauer J, Anwander A, Perani D, Friederici AD.](#) Dorsal and ventral pathways in language development. [Brain Lang.](#) 2013 May 1.





Étude en tractographie des déficits phono-auditifs et orthographiques dans la dyslexie : dissociation entre une voie inférieure (faisceau fronto-occipital inférieur ou I.F.O.F.) et supérieure (faisceau arqué) dans la substance blanche de l'hémisphère gauche.

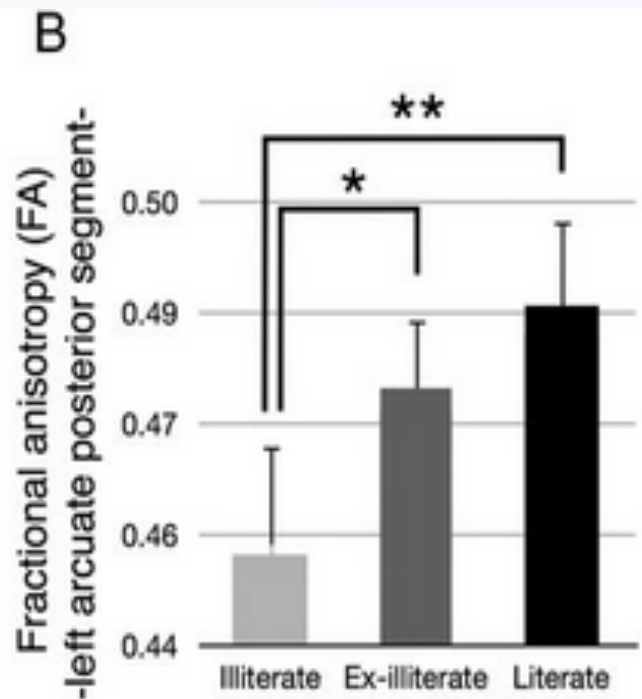
La voie supérieure et la voie inférieure sont respectivement corrélées avec l'efficacité dans une tâche de conscience phonologique et dans une tâche de traitement orthographique en lecture.

*D'après Vandermosten et al., 2012.*

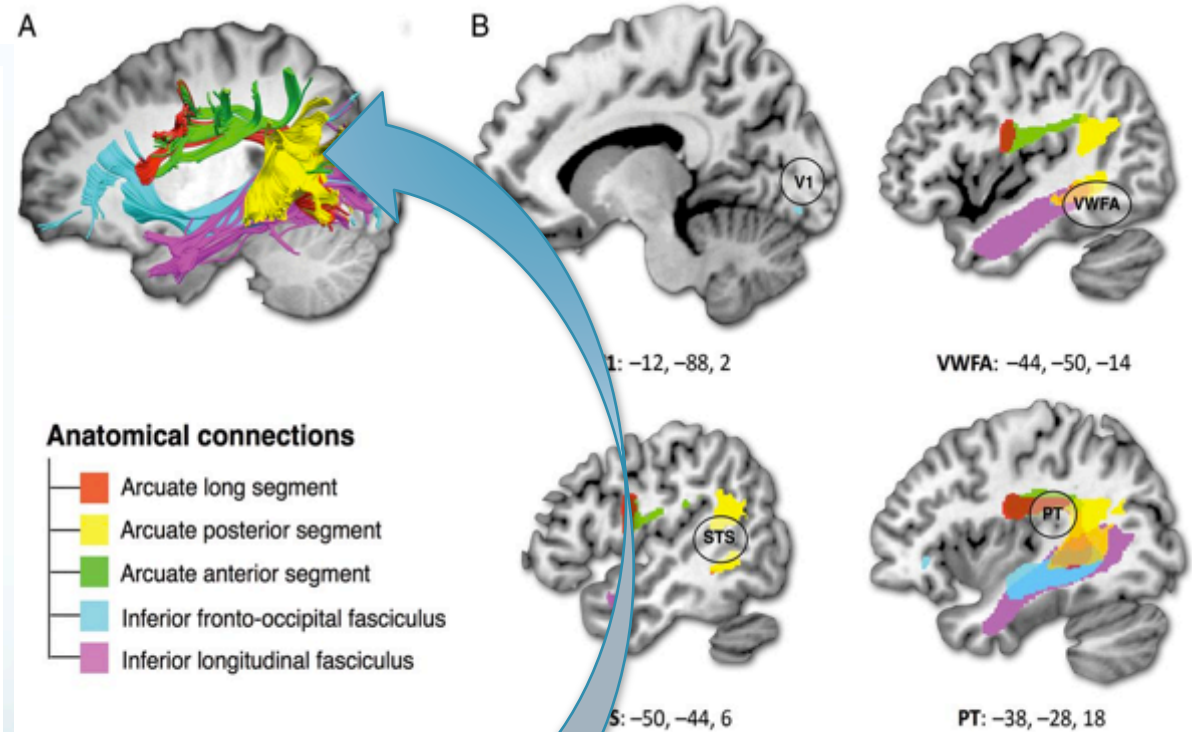


## Learning to Read Improves the Structure of the Arcuate Fasciculus

Michel Thiebaut de Schotten<sup>1,2,3,4</sup>, Laurent Cohen<sup>3,4,5</sup>, Eduardo Amemiya<sup>6</sup>, Lucia W. Braga<sup>6</sup> and Stanislas Dehaene<sup>7,8,9,10</sup>



- Illettrés (n= 10) : proviennent de la région rurale (5) ou urbaine (5) des environs de Brasilia
- « Participants were illiterates for social reasons, with no history of special difficulty other than the lack of access to schools. »
- Ex-illettrés (n= 10) : parcours similaire à celui des illettrés (parents illettrés de secteur rural) mais ont reçu un enseignement à l'âge adulte.
- Non-illettrés : (n= 11) proviennent de la même communauté sociale que les illettrés mais ont appris à lire pendant l'enfance.



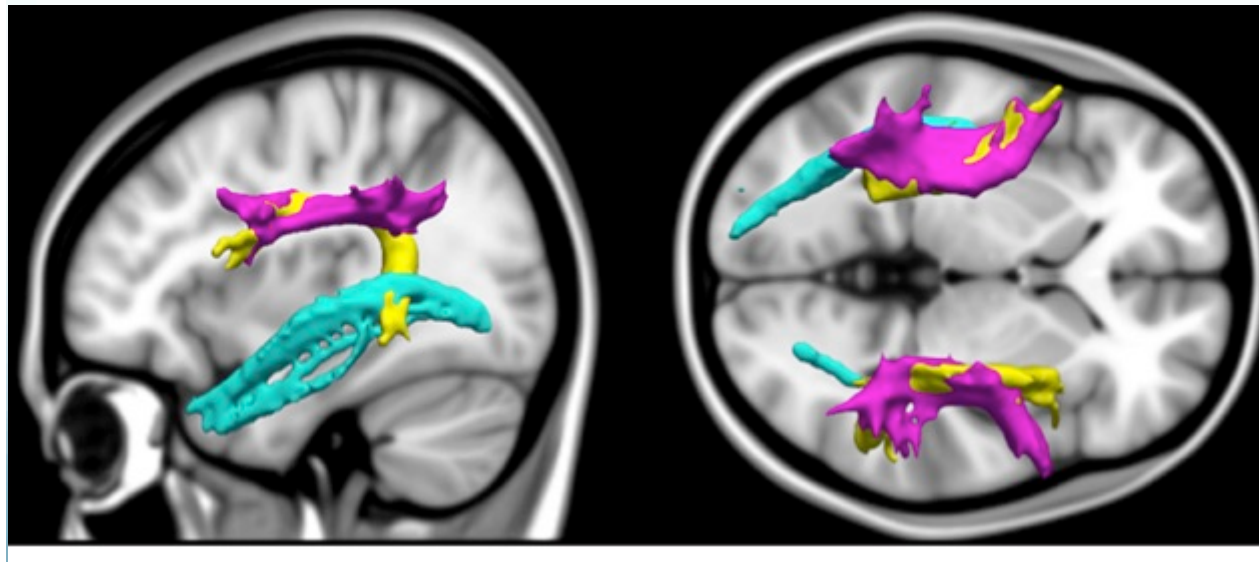
Partie postérieure du faisceau arque:  
Volume inversement proportionnel au degré d'illettrisme

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,<sup>1\*</sup> Elizabeth S. Norton,<sup>1\*</sup> David E. Osher,<sup>1</sup> Sara D. Beach,<sup>1</sup> Abigail B. Cyr,<sup>1</sup> Ola Ozernov-Palchik,<sup>3</sup> Anastasia Yendiki,<sup>4</sup> Bruce Fischl,<sup>2,4</sup> Nadine Gaab,<sup>3</sup> and John D.E. Gabrieli<sup>1</sup>

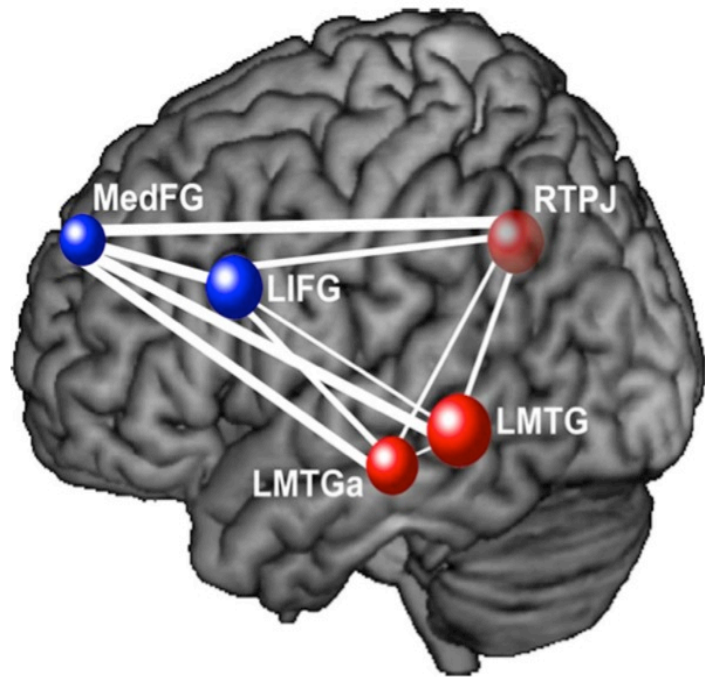
<sup>1</sup>McGovern Institute for Brain Research and Department of Brain and Cognitive Sciences and <sup>2</sup>Computer Science and Artificial Intelligence Laboratory



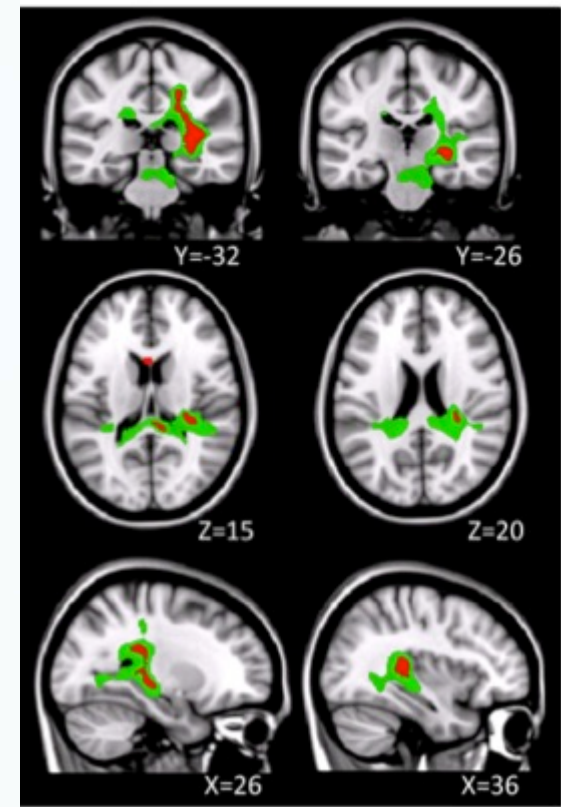
In kindergarten children, we found a correlation between phonological awareness for spoken language and indices of white matter organization of the left arcuate fasciculus, specifically volume and FA. This relationship was both anatomically and behaviorally specific; it was not observed in other tracts (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 independent 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, exists before formal reading instruction and substantial reading experience favors the view that differences in

# En définitive

- Le faisceau arqué apparaît comme le principal et le plus robuste marqueur anatomique de la dyslexie
- Sa morphologie varie de façon notable chez l'adulte en fonction du degré d'illettrisme
- Chez l'enfant, son développement est en partie contemporain de l'acquisition de la lecture
- Les différences sont cependant déjà présentes avant l'apprentissage de la lecture et proportionnelles aux aptitudes phonologiques
- Elles s'atténuent après une rééducation efficace



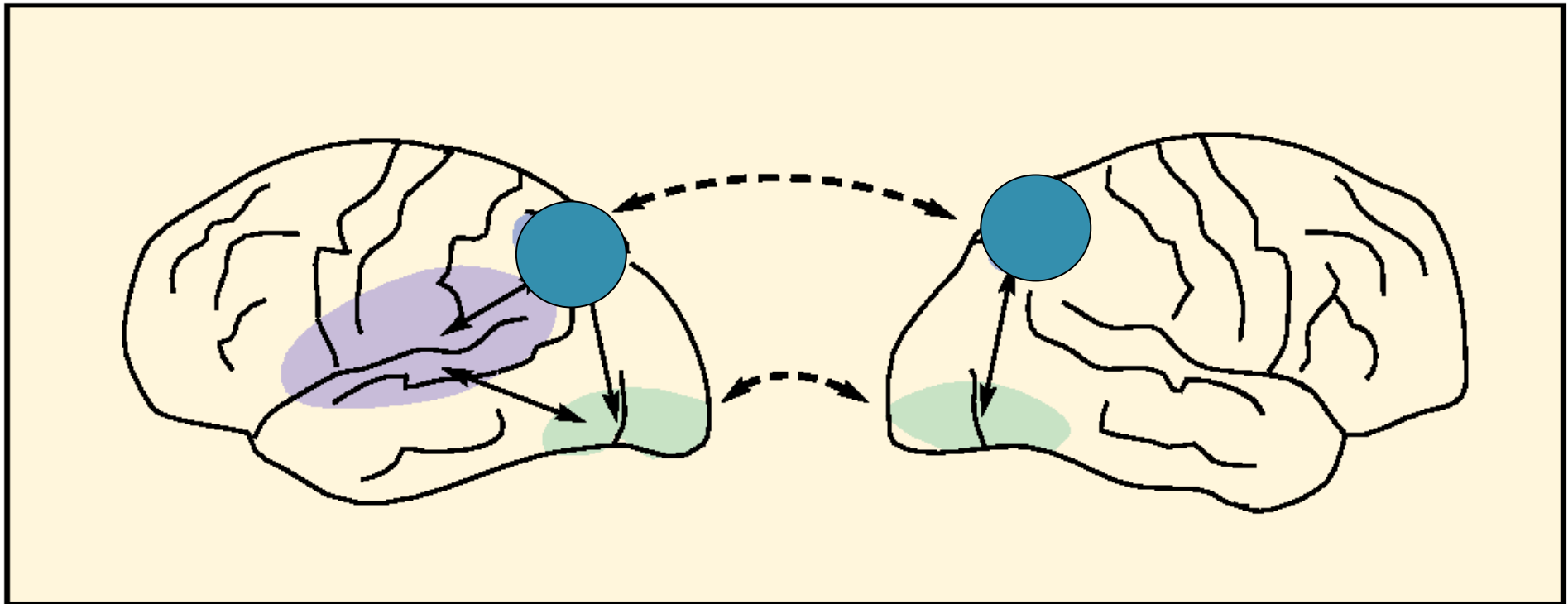
**Autisme:** diagramme représentant le défaut de connectivité observé en IRMf lors d'une tâche de compréhension de texte. L'épaisseur des traits représente la significativité de la différence entre autistes et témoins. (Mason et al., 2008)



**Dyscalculie :** « DTI tractography suggests that long-range WM projection fibers linking the right fusiform gyrus with temporal-parietal GM are a specific source of vulnerability in DD » (Rykhlevskaia et al., 2009)



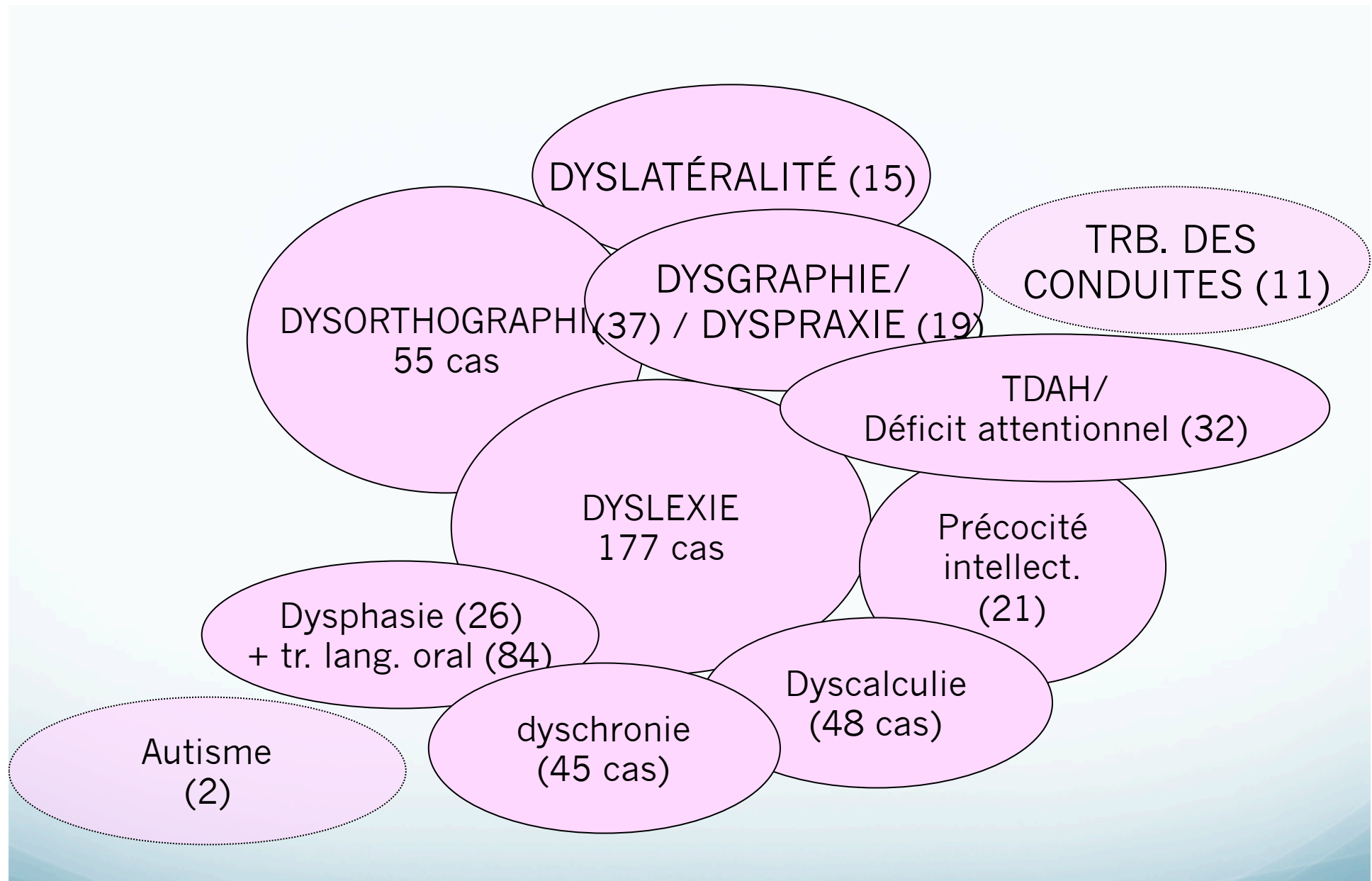
Dyscalculie : défaut de connectivité entre les zones du traitement analogique (aire du « sens des nombres ») et les zones du langage oral et écrit



**Figure 3** - Implémentation anatomique du triple code (traitement visuel arabe en vert, traitement analogique en bleu et traitement langagier en violet).

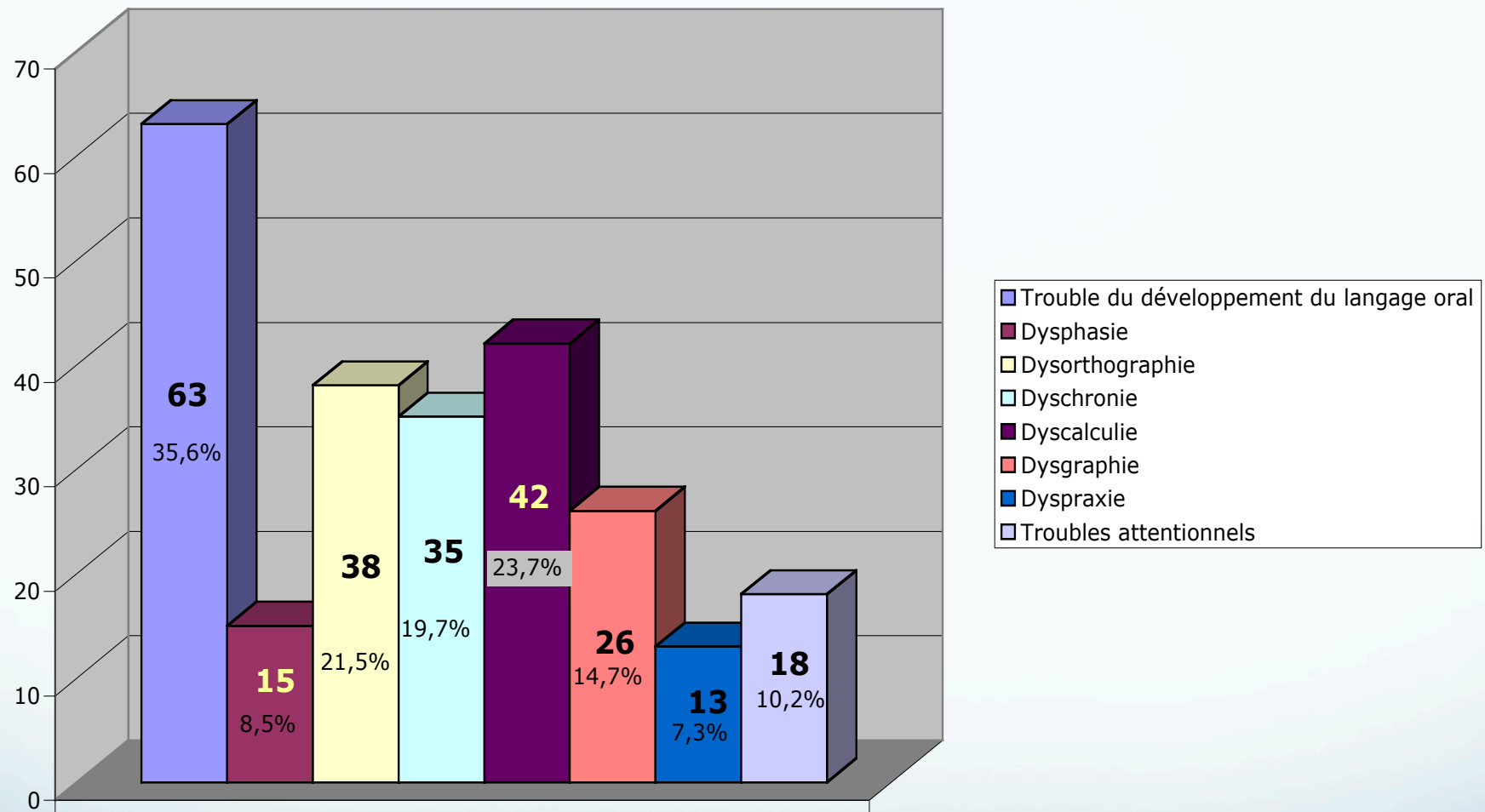


# Dysconnectivité inter-modalitaire : focus sur les comorbidités



Inventaire des diagnostics posés chez 209 patients de 7 à 15 ans reçus successivement à une consultation spécialisée de troubles d'apprentissage

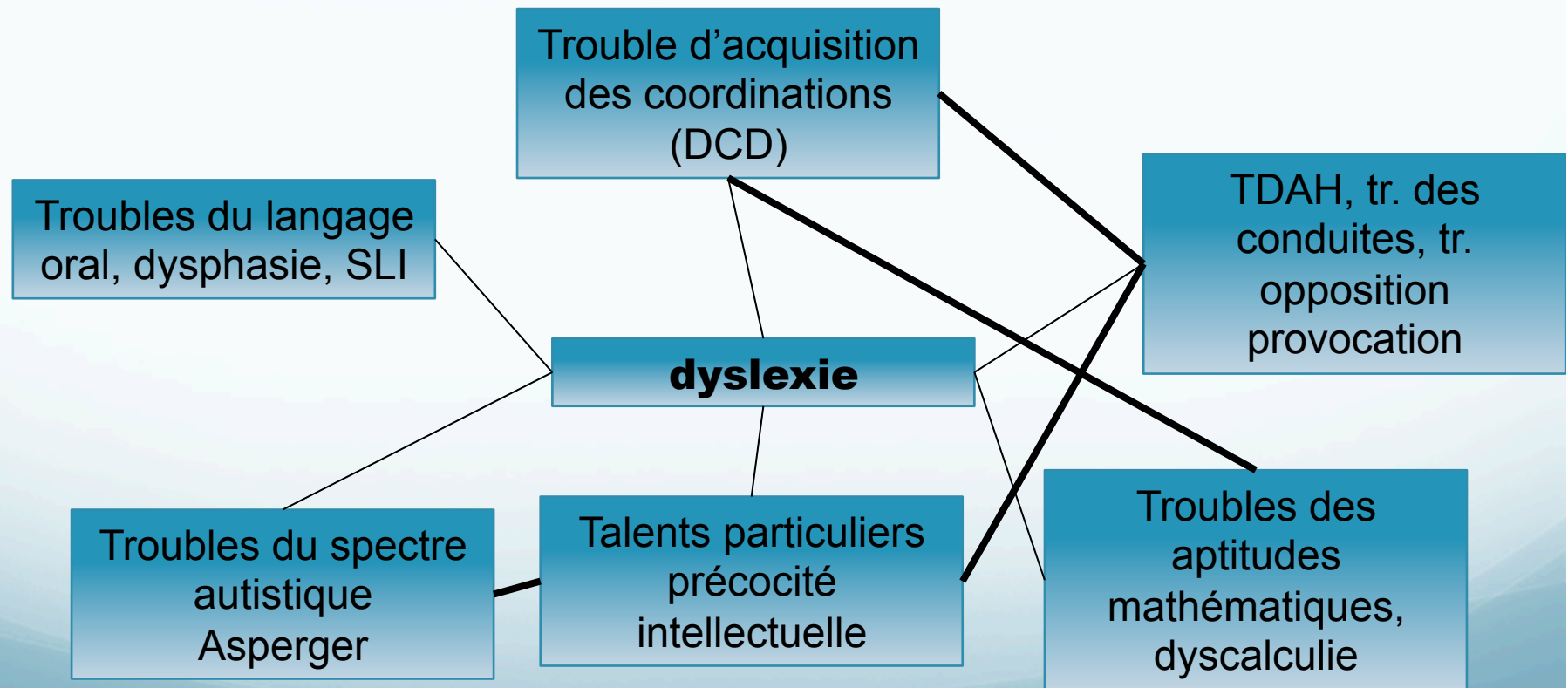
## dyslexie (N=177) : comorbidités



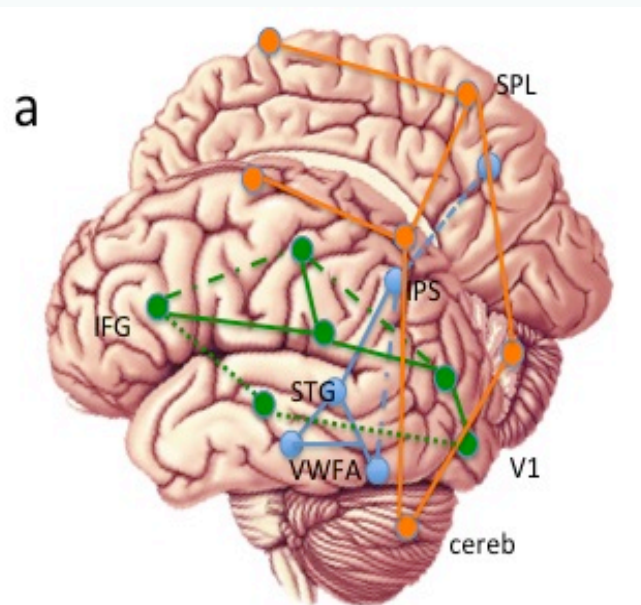
La dyslexie est plus souvent associée à d'autres troubles dys

Les regroupements ne se font pas de façon aléatoire mais réalisent des patrons ou clusters caractéristiques

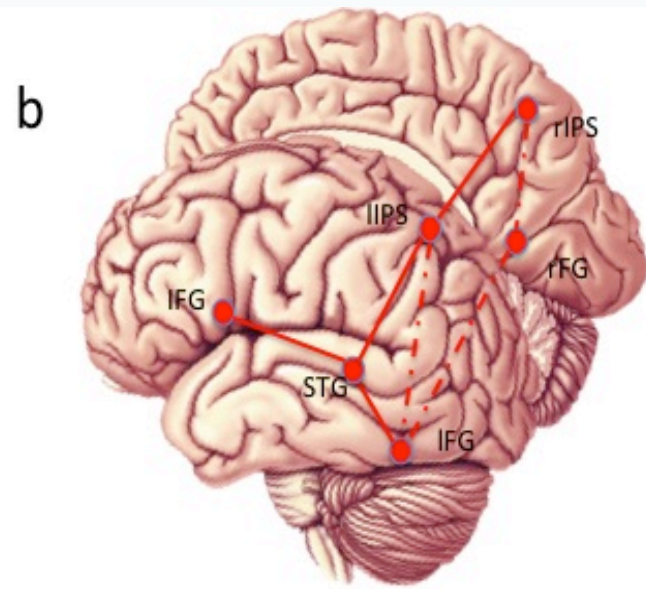
# Troubles d'apprentissage: un modèle général centré sur la notion de comorbidité



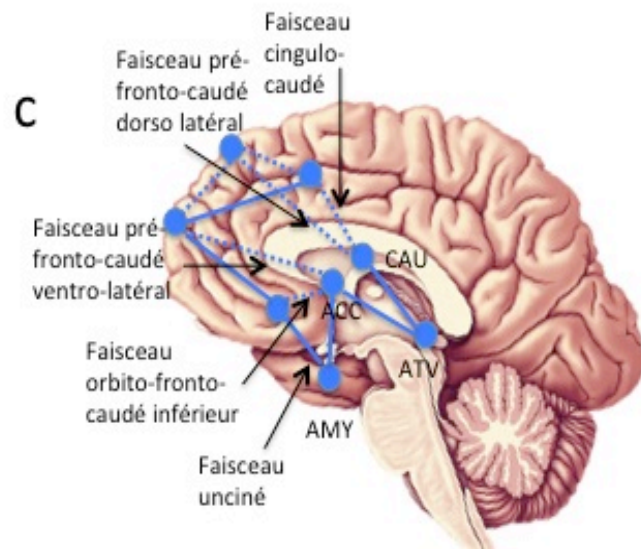
dyslexie



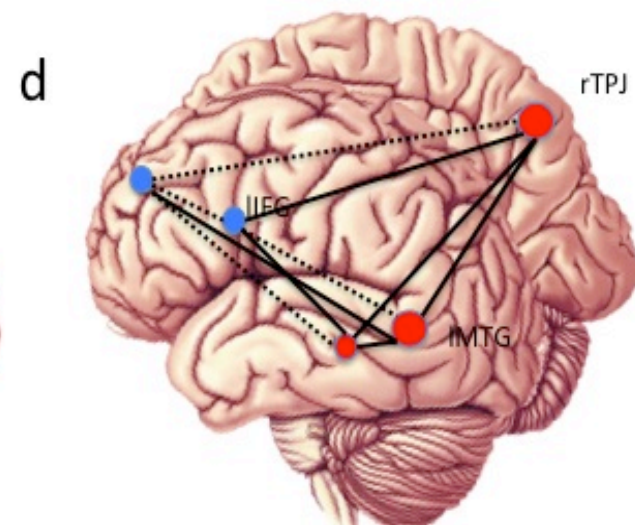
dyscalculie



TDAH



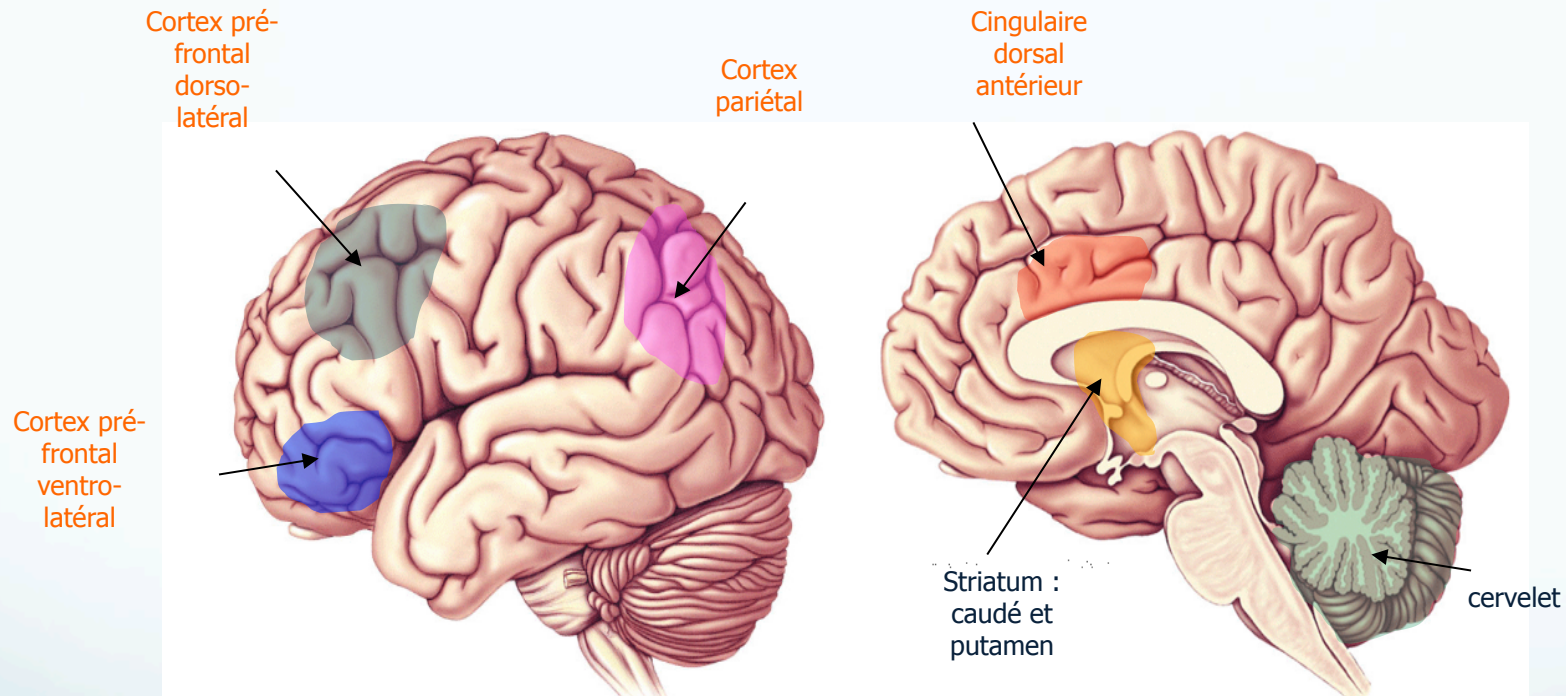
autisme





## Attention-Deficit/Hyperactivity Disorder and Attention Networks

George Bush<sup>1,2,3,4</sup>



Les principales régions cérébrales dysfonctionnelles dans le TDAH (méta-analyse)

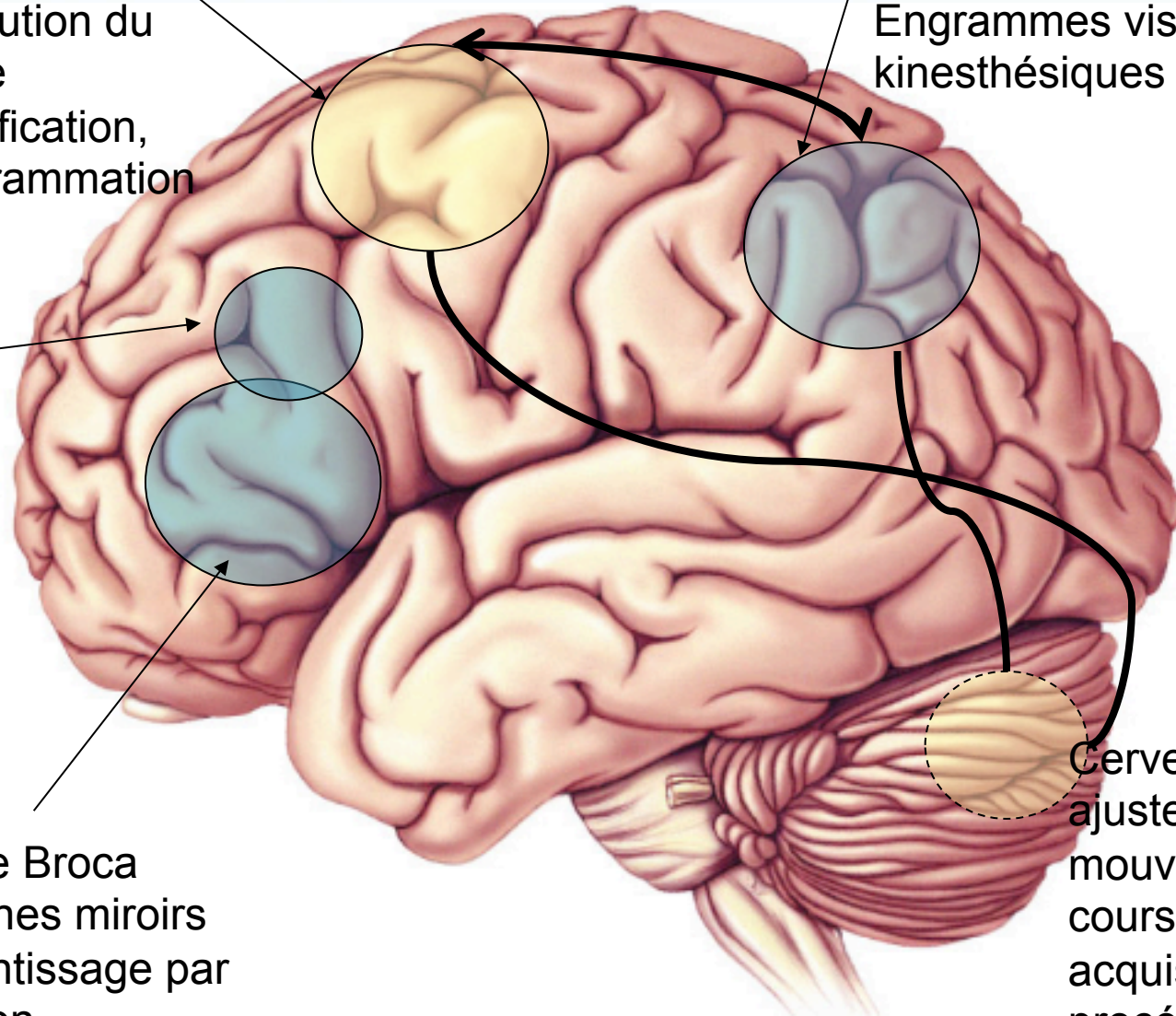
Cortex frontal  
(DLPFC)  
Exécution du geste  
Planification,  
programmation

Lobe pariétal :  
préparation du geste  
Engrammes visuo-  
kinesthésiques

Aire d'Exner :  
programmation  
du geste  
graphique

Aire de Broca  
Neurones miroirs  
Apprentissage par  
imitation

Cervelet :  
ajustement du  
mouvement en  
cours,  
acquisition de  
procédures,  
timing du  
mouvement



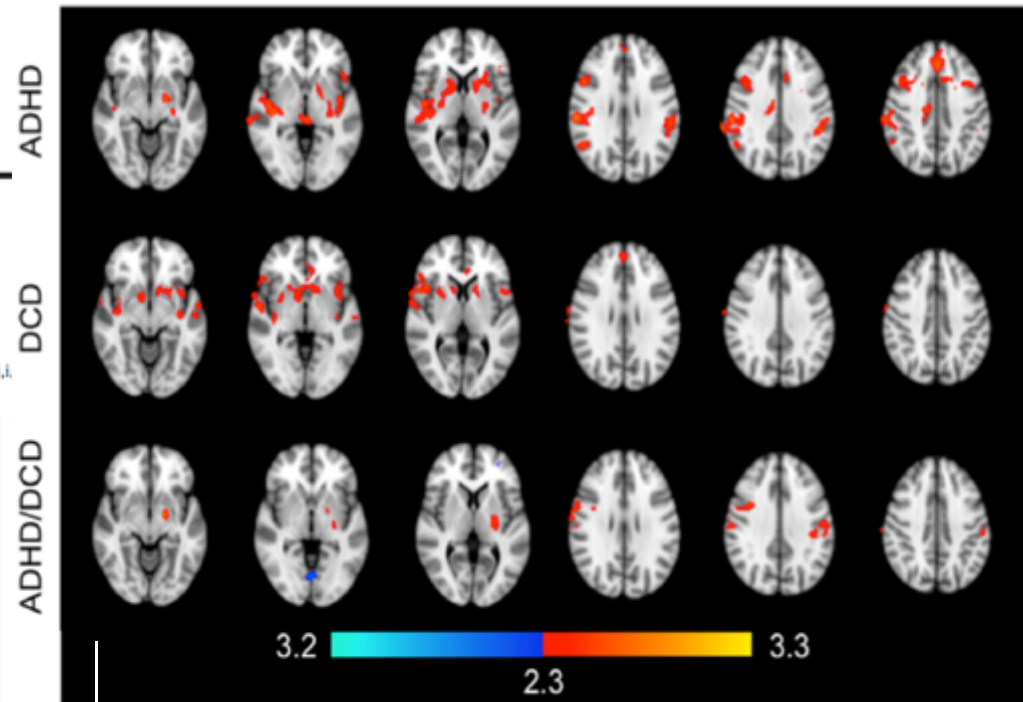


## Functional connectivity of neural motor networks is disrupted in children with developmental coordination disorder and attention-deficit/hyperactivity disorder

Kevin R. McLeod<sup>a,c</sup>, Lisa Marie Langevin<sup>b,c,d</sup>, Bradley G. Goodyear<sup>e,f,g,h,i</sup>, Deborah Dewey<sup>b,c,d,j,i</sup>

<sup>a</sup>Medical Science, University of Calgary, Calgary, Alberta, Canada

Compared to typically developing controls, children with DCD and/or ADHD exhibit FC alterations between M1 and brain regions involved in motor functioning and sensorimotor processing. Our findings support the hypothesis that common neurophysiological substrates underlie



Evidence from neuroimaging research suggests that children with these disorders exhibit disruptions in motor circuitry, which could account for the high rate of co-occurrence. The primary objective of this study was to investigate the functional connections of the motor network in children with DCD and/or ADHD compared to typically developing controls, with the aim of identifying common neurophysiological substrates. Resting-state fMRI was performed on seven children with DCD, 21 with ADHD, 18 with DCD + ADHD and 23 controls.

**Table 1**  
Participant characteristics.

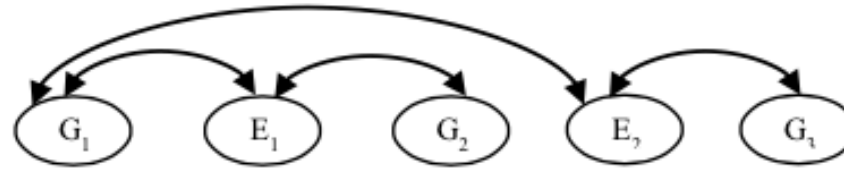
	Controls	ADHD	DCD	DCD + ADHD
Age in years	11.3 ± 2.8	12.5 ± 2.9	13.0 ± 2.5	11.5 ± 3.0
N (females)	23 (12)	21 (1) <sup>a</sup>	7 (2)	18 (4)
Left-handed	2	2	1	4
WASI IQ	113.0 ± 13.4	105.4 ± 11.8	107.0 ± 13.0	104.8 ± 15.8
CPRSC-C score	51.7 ± 9.5	72.5 <sup>a,b</sup> ± 8.7	50.9 ± 3.9	72.2 <sup>a,b</sup> ± 12.0
CPRSC-H score	51.6 ± 9.4	71.1 <sup>a,b</sup> ± 14.1	49.7 ± 3.4	65.0 <sup>a,b</sup> ± 13.8
MABC-2 score	10.1 ± 2.2	9.5 ± 1.6	5.1 <sup>a,c</sup> ± 2.0	4.4 <sup>a,c</sup> ± 2.2



Niveau d'analyse

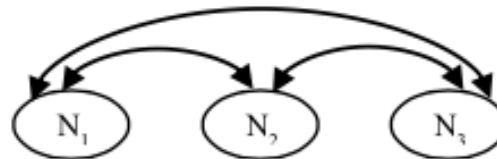
Non-indépendance à chaque niveau

Risques étiologiques et facteurs protecteurs



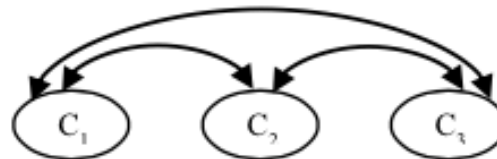
Interaction G x E et corrélation GE

Systèmes neuraux



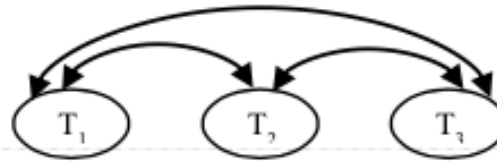
Pléiotropie

Processus cognitifs



Développement interactif

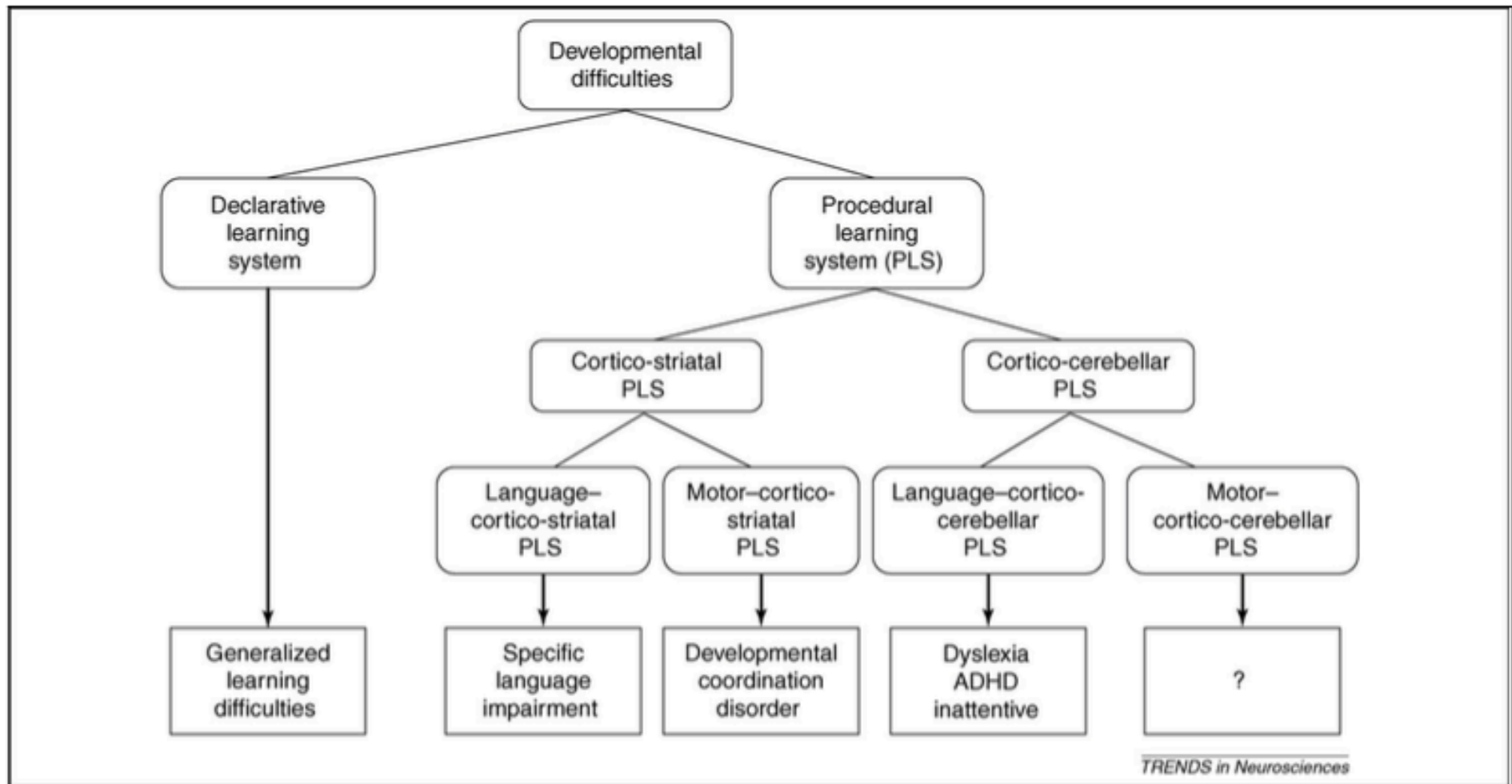
Troubles comportementaux complexes



Comorbidité

Comorbidités : Modèle probabiliste et multifactoriel de Pennington (2009)

G = facteur de risque ou facteur protecteur génétique, E = facteur de risque ou facteur protecteur environnemental, N = système neural, C = processus cognitif, T = trouble.



Théorie procédurale de Nicolson et Fawcett (2007)

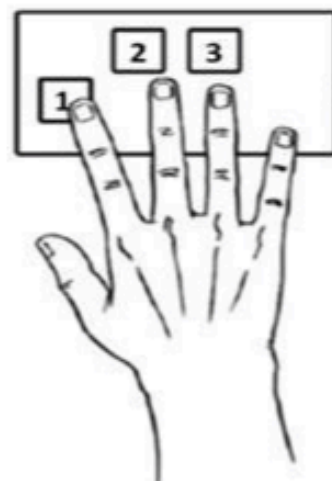


OS = Séquence Automatisée

1-2-1-2-3

5min/jour pendant 15 jours

Consolidée et Automatisée



NS = Séquence Nouvelle

2-3-1-3-1

Nouvellement apprise

le jour même

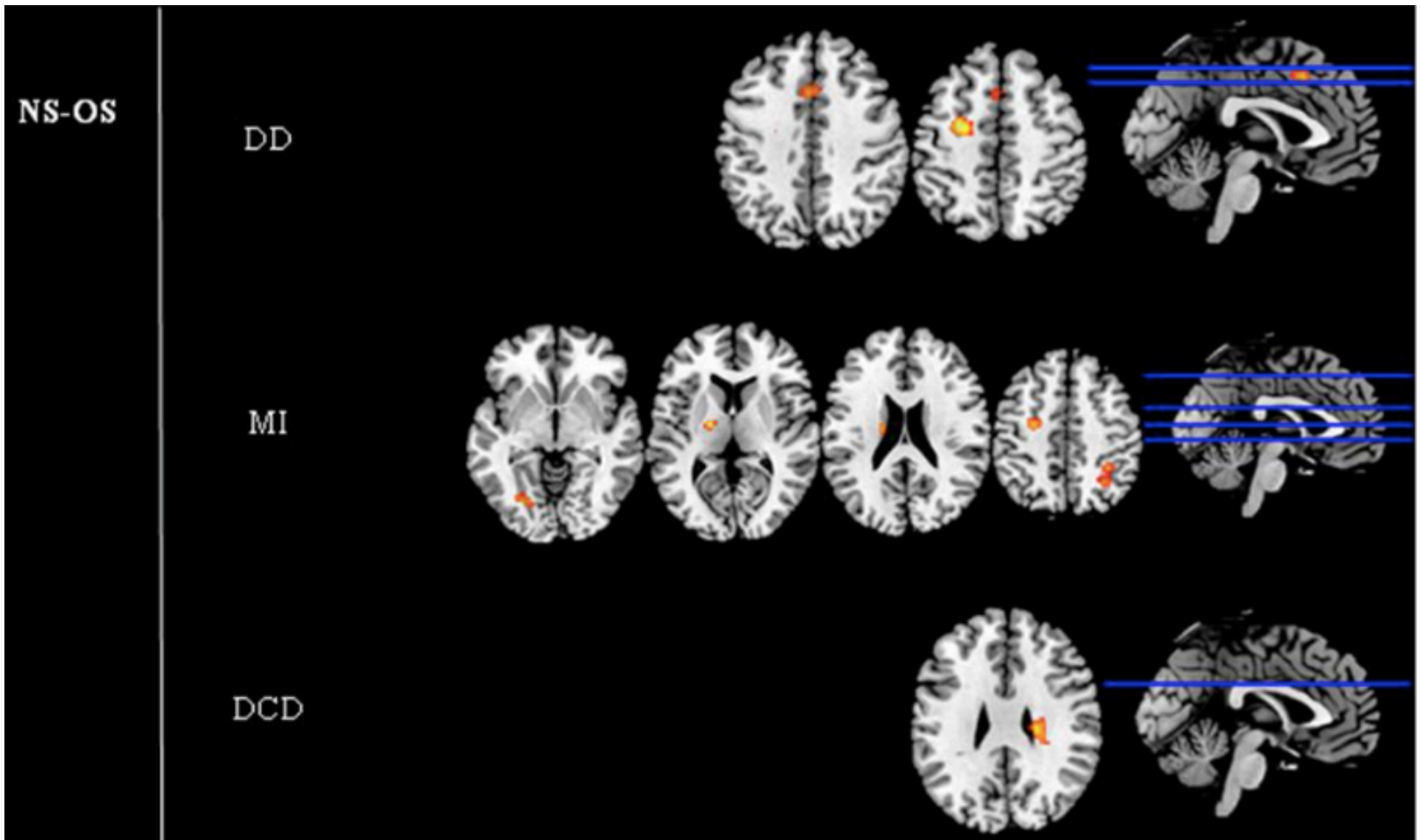
Tableau 5 : Caractéristiques démographiques et cliniques des participants

	TAC	DD	DysTAC	Test
<b>Enfants (N)</b>	16	16	16	
Garçons	12 (75%)	9 (56.3%)	10 (62.5%)	Khi = 1.3. df = 2. p = .53
Filles	4 (25%)	7 (43.8%)	6 (37.5%)	
Age, Moyenne (ET)	9.6 (1.7)	10.3 (1.3)	9.9 (1.1)	F(2.47) = 0.968. p = .388
<b>M-ABC*</b>				
MABC score total	25.7 (5.8)	4.6 (3.7)	25.8 (6.6)	F(2.47) = 78.116. p < .001
MABC dextérité manuelle	12.5 (2.9)	3.0 (2.8)	10.3 (3.9)	F(2.47) = 37.173. p < .001
MABC lancer de balles	5.3 (2.4)	1.0 (1.5)	7.0 (3.9)	F(2.47) = 19.695. p < .001
MABC équilibre	7.8 (4.8)	0.6 (1.1)	8.6 (4.6)	F(2.47) = 20.715. p < .001
<b>Echelle de lecture**</b>				
Score Composite CM/CTL	0.2 (0.5)	-2.1 (0.6)	-1.9 (0.6)	F(2.47) = 68.384. p < .001
<b>WISC-IV</b>				
QIT	103.9 (13.1)	110.3 (14.0)	99.6 (18.7)	F(2.47) = 1.915. p = .159

\* Différences significatives dans tous les subtests moteurs entre DD et TAC avec ou sans DD

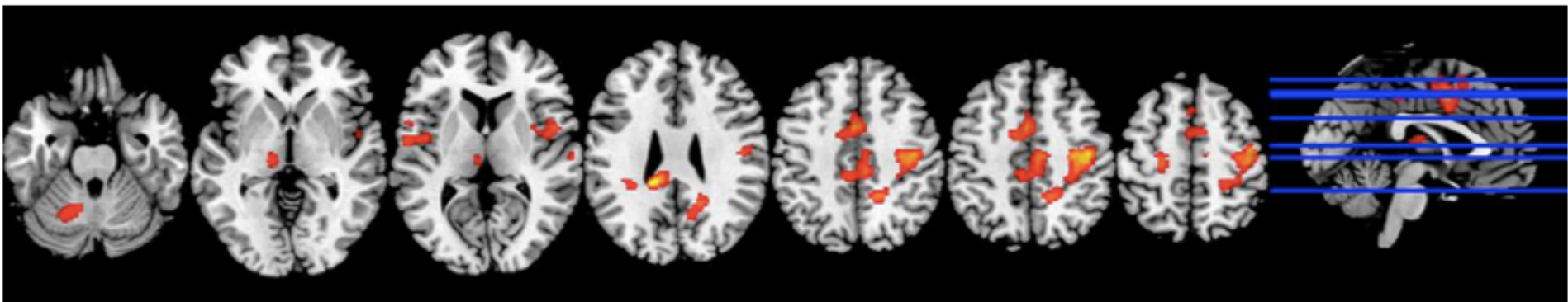
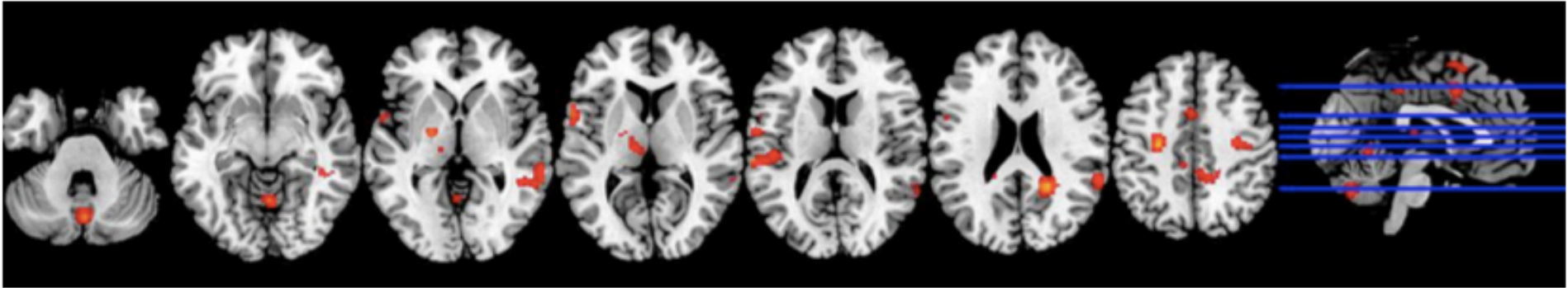
\*\* Différences significatives dans tous les subtests de lecture entre TAC et DD avec ou sans TAC

Thèse Maelle  
Biotteau (Toulouse)



Résultat 1 : Dans les trois groupes : la tâche automatisée active moins les zones corticales, cingulaire et striatale (comme attendu)

TAC > DysTAC



TAC > Dys

Résultat 2 lors de la tâche automatisée : suractivation des TAC dans les deux systèmes : cortico-striatal et cortico-cérébelleux (contraire à l'hypothèse de Nicolson)

# Neurobiological Underpinnings of Math and Reading Learning Disabilities

Sarit Ashkenazi, PhD<sup>1</sup>, Jessica M. Black, PhD<sup>2</sup>, Daniel A. Abrams, PhD<sup>1</sup>, Fumiko Hoeft, MD, PhD<sup>3</sup>, and Vinod Menon, PhD<sup>1</sup>

Journal of Learning Disabilities  
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DOI: 10.1177/0022219413483174  
journaloflearningdisabilities.sagepub.com  
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In spite of a near 50% rate of comorbidity between RD and MD, these conditions appear to be associated with two independent cognitive deficits, namely a core phonological deficit in the case of RD and a deficit in number sense in the case of MD (Landerl et al., 2009). The distinct neurocognitive profiles are reflected in the differential role of the left ventral fronto-temporal- parietal language circuits (IFG, STG/MTG, and IPL) in RD, and the predominantly right lateralized dorsal fronto-parietal circuits (PMC/MFG and IPS/SPL) in MD.

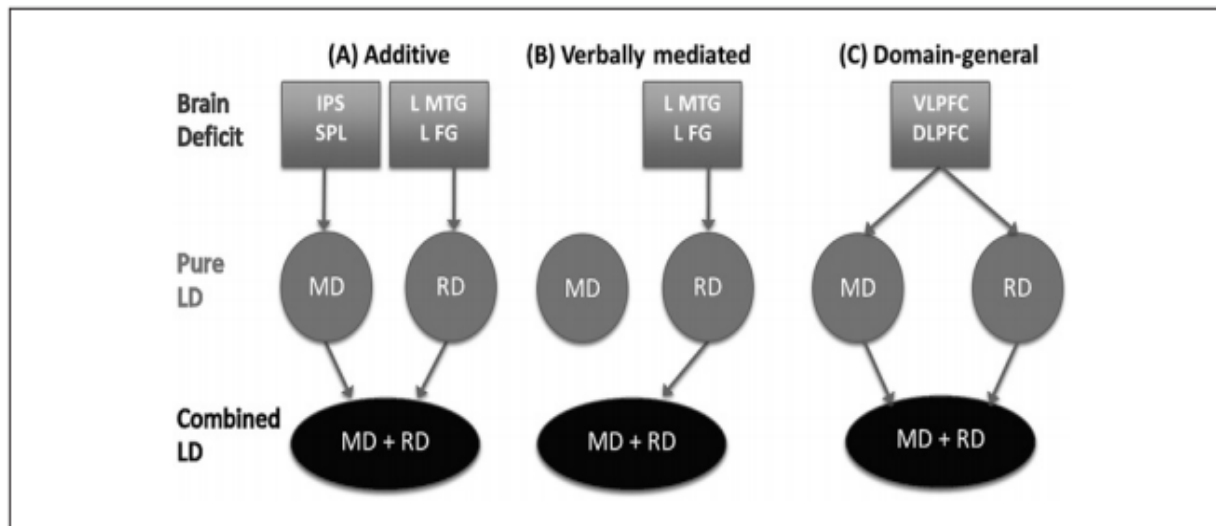


Figure 1. Neurobiological pathways underlying math and reading disability (MD+RD) comorbidity. Schematic illustration of putative





### Gray–white matter and cerebrospinal fluid volume differences in children with Specific Language Impairment and/or Reading Disability

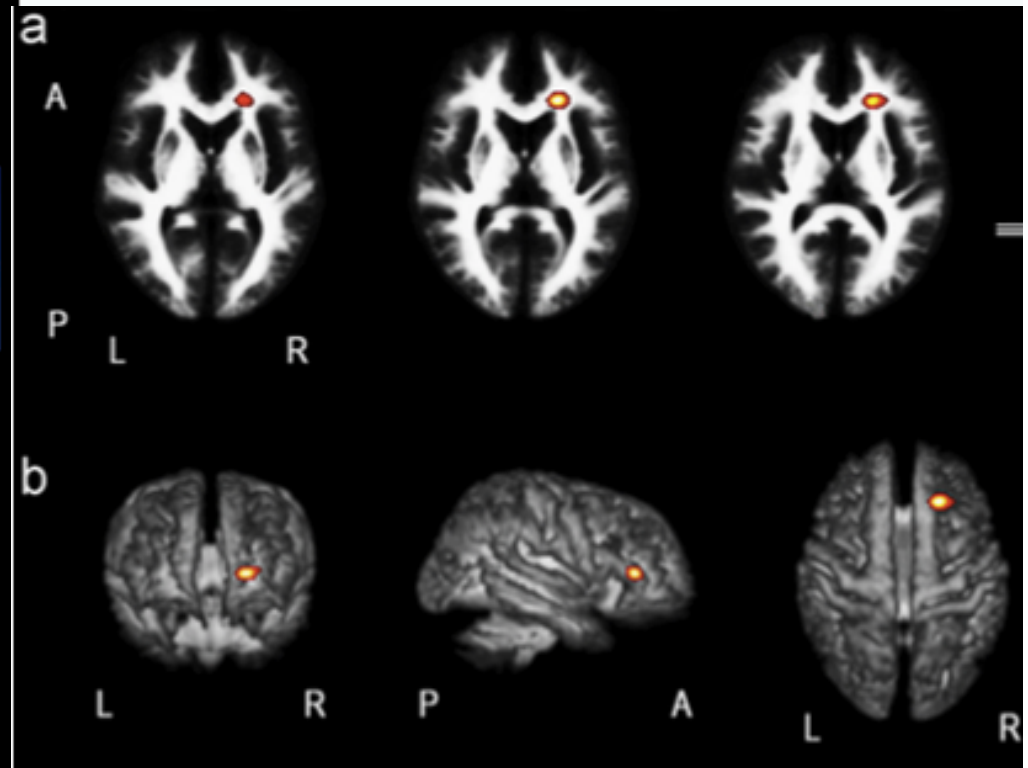
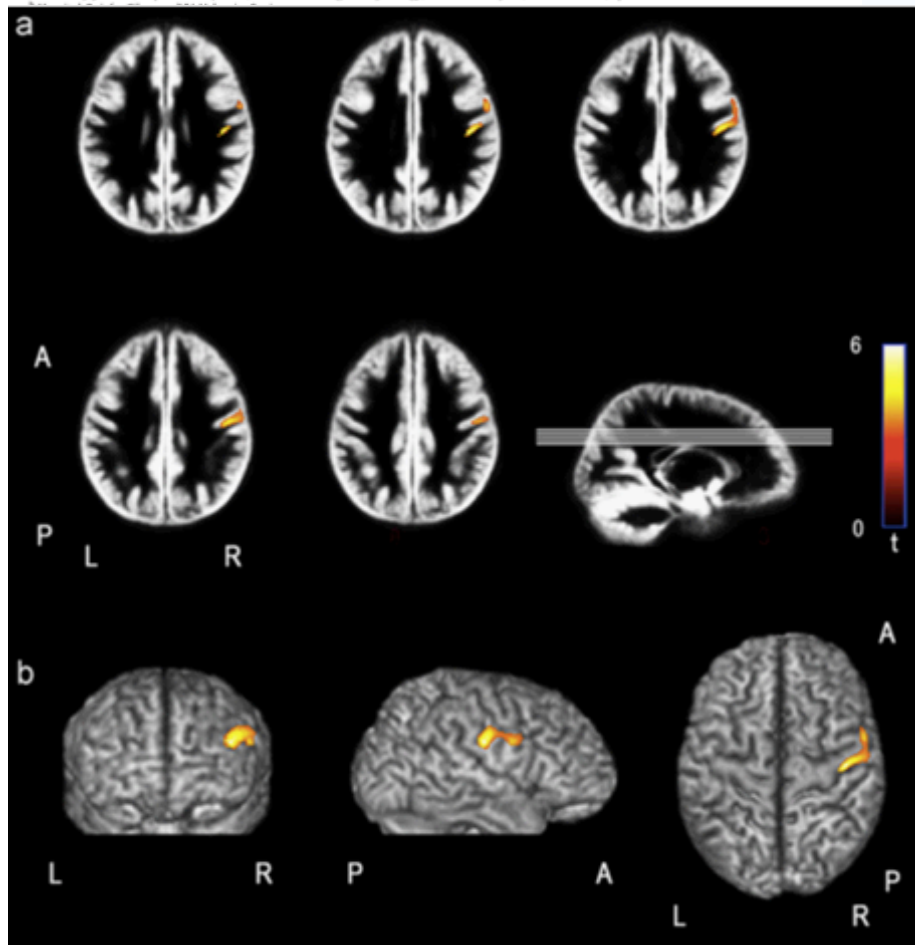
Dolors Girbau-Massana <sup>a,\*</sup>, Gracian Garcia-Marti <sup>b</sup>, Luis Marti-Bonmati <sup>b</sup>, Richard G. Schwartz <sup>c</sup>

<sup>a</sup> University Jaume I, Department of Basic, Clinical & Biological Psychology, Vicent Sos Baynat, 12071 Castelló, Spain

10 SLI; 6 SLI +dyslexie; 16 controls

SLI : ↓ SG gyrus angulaire DT

SLI+ DYS : ↓SG gyrus post-central droit  
↓SB : faisceau longitudinal inférieur droit



Significant smaller GM SLI+DYS/cont

Significant smaller WM SLI+DYS/cont





## An fMRI study of nonverbally gifted reading disabled adults: has deficit compensation effected gifted potential?

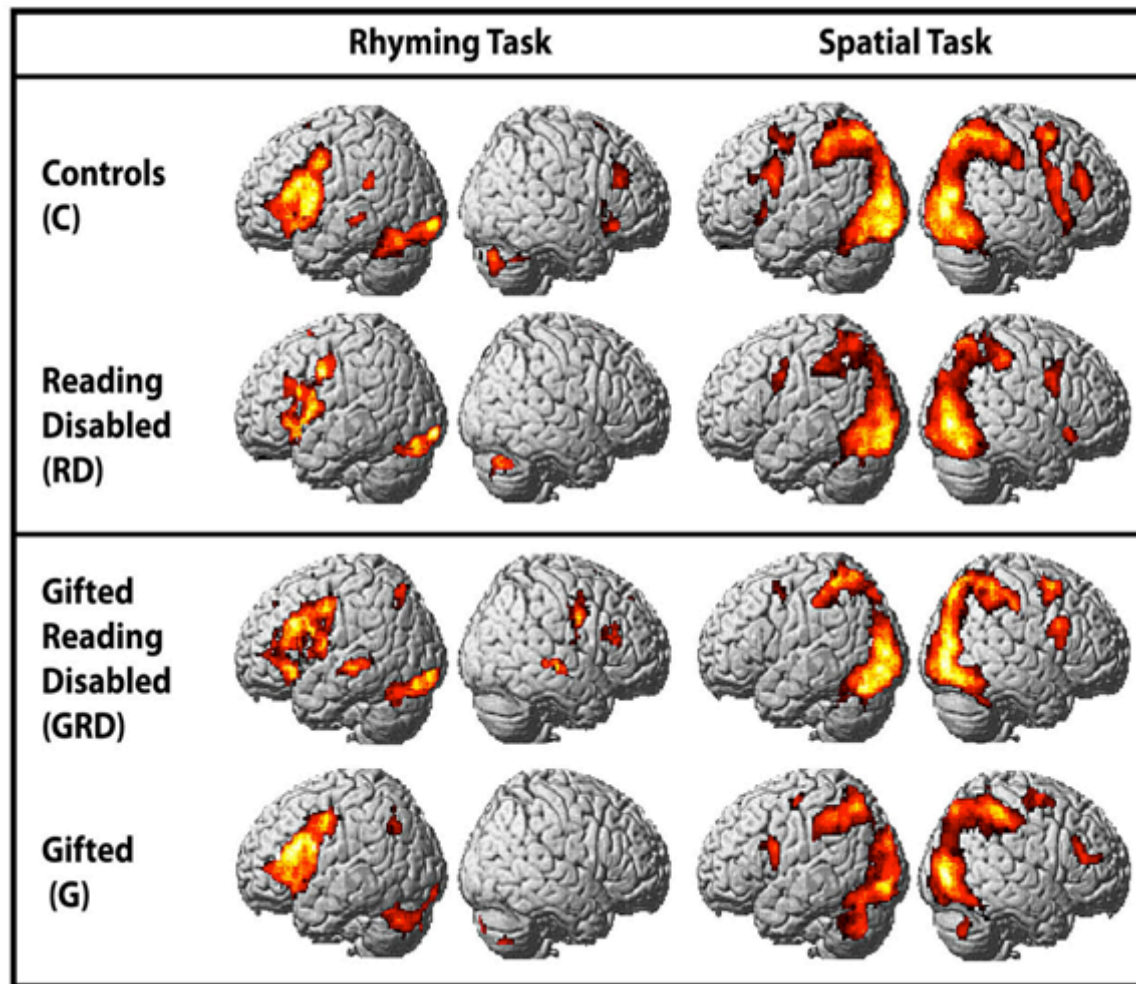
Jeffrey W. Gilger<sup>1\*</sup>, Thomas M. Talavage<sup>2,3</sup> and Olumide A. Olulade<sup>3,4</sup>

<sup>1</sup> Psychological Sciences, University of California Merced, Merced, CA, USA

<sup>2</sup> Weldon School of Biomedical Engineering, Purdue University, West Lafayette, IN, USA

<sup>3</sup> The School of Electrical and Computer Engineering, Purdue University, West Lafayette, IN, USA

<sup>4</sup> Center for the Study of Learning, Department of Pediatrics, Georgetown University Medical Center, Washington, DC, USA

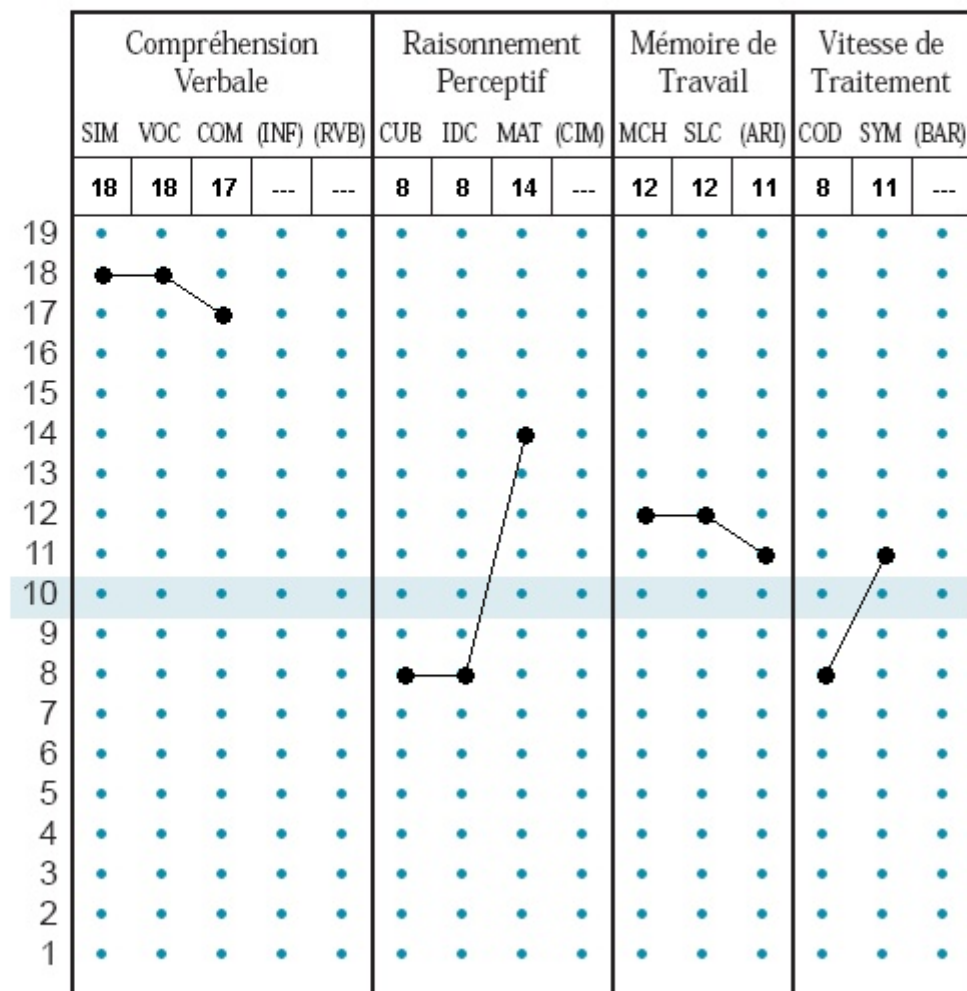


non-verbally gifted RD adults resemble non-gifted RD adults in their performance on paper- and-pencil reading, math and spatial tests, and in their patterns of functional activation during reading and spatial processing. In our opinion, a shared etiology of RD and giftedness can yield a lifespan interaction with reading compensation effects modifying how an adult brain processes text and spatial stimuli.

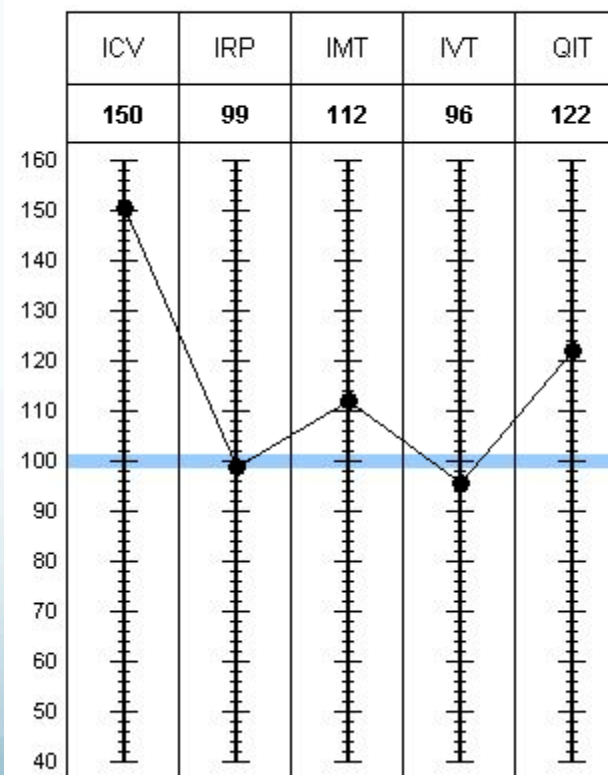
**Lolita : 6 ans 11 mois.** CE1.aucun retard ni moteur ni langage ni écriture.  
Lecture acquise après un mois de CP. S'ennuie en classe, turbulente.

Difficultés en mathématiques.

Profil des notes standard

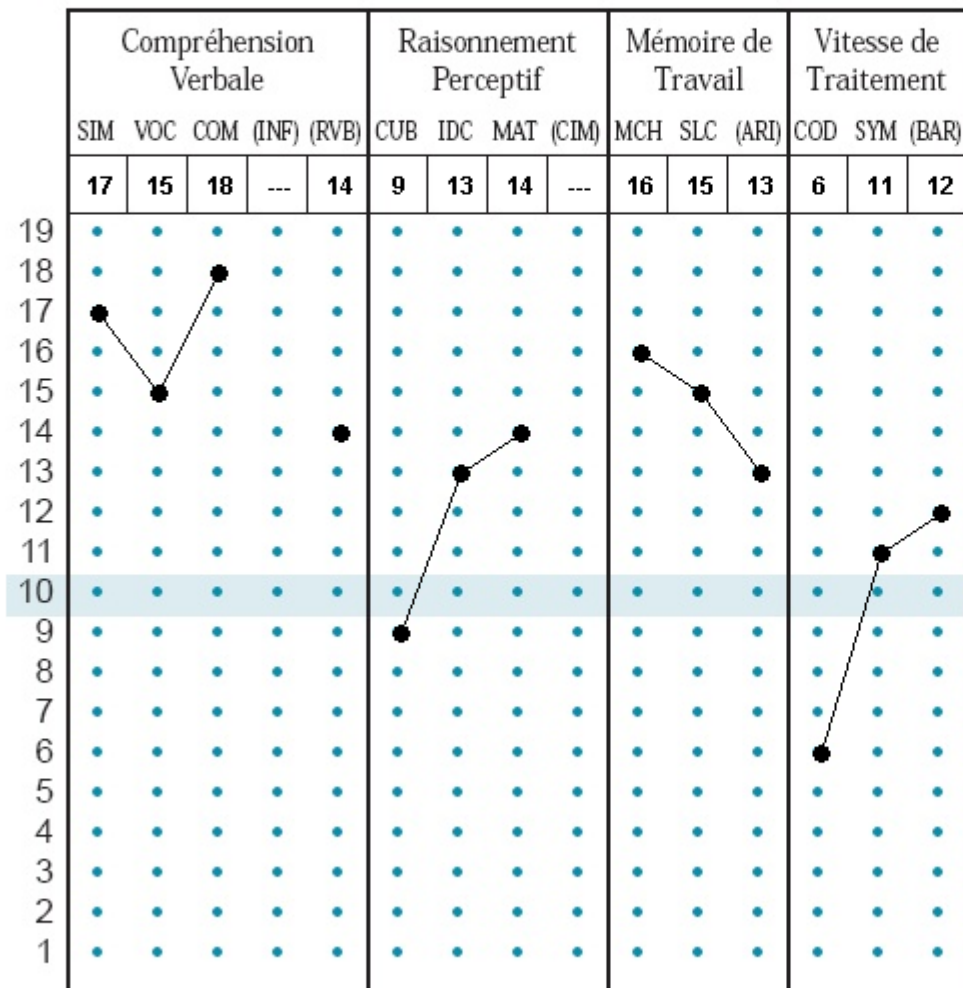


Profil des notes composites

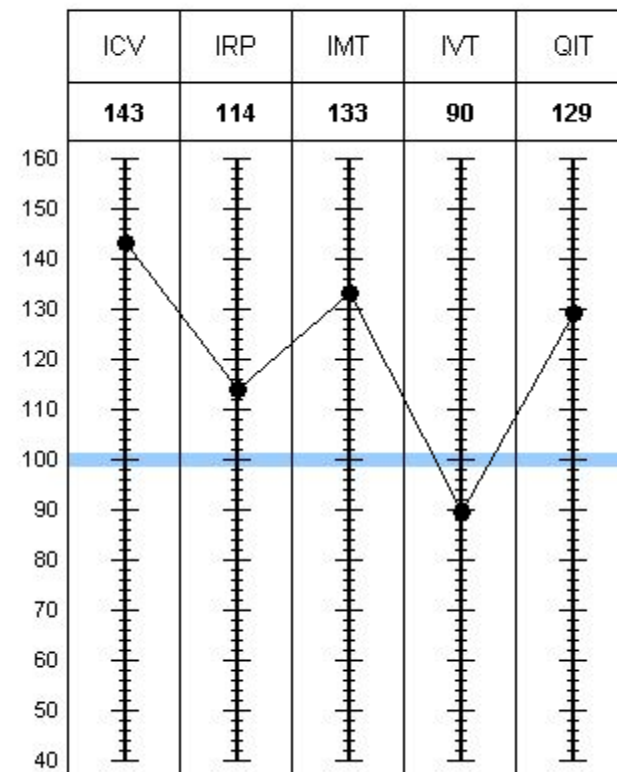


**Leny (frère de Lolita) : 10 ans 4 mois.** Aucun retard ni de motricité ni de parole mais ne sait pas encore faire ses lacets. Tenue du crayon non acquise. Dysgraphie. Refus de passage à l'écrit. Aucun respect des règles. Comportement à risque et troubles des conduites. Conners-hyperactivité : 22/30

Profil des notes standard



Profil des notes composites



**Ecriture sous dictée**

**Dysgraphie patente**

Je respire le doux parfum  
des fleurs

# GRILLE D'EVALUATION PSYCHOMOTRICE

Nom et prénom de l'enfant :

Date de naissance :

Age :

Latéralité :

Main :

Nom du praticien :

Date de passation du bilan :

Œil :

Pied :

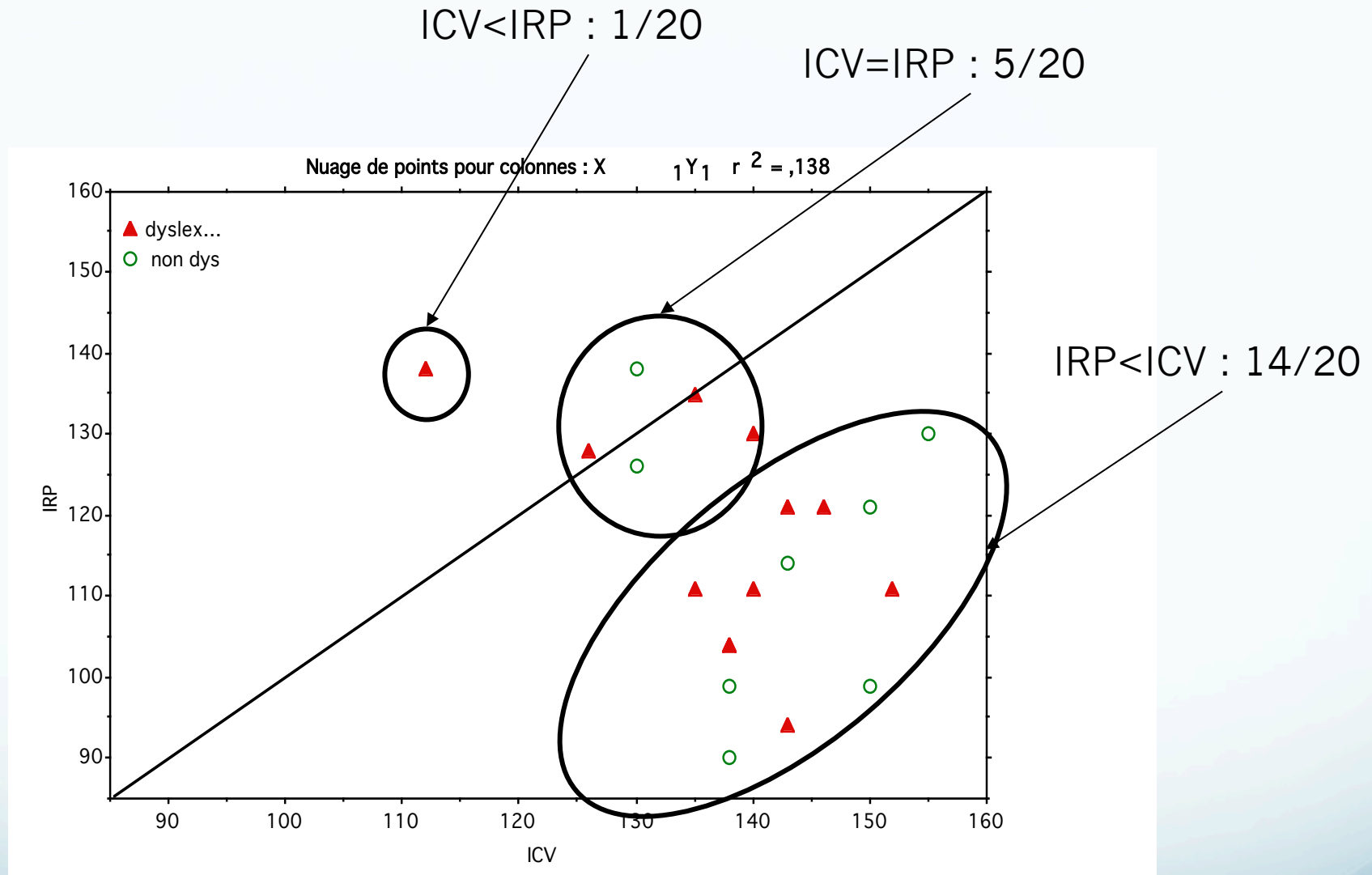
Tonus :

D'action :

De fond :

		MOTRICITE GENERALE		COORDINATIONS MANUELLES		SCHEMA CORPOREL			ESPACE		TEMPS		ECRITURE		PLANIFICATION	IMPULSIVITE		
> MOYENNE																		
MOYENNE																		
Déviance de la norme	NORMAL FAIBLE																	
	DISCRETEMENT PATHOLOGIQUE																	
Pathologique	PATHOLOGIQUE																	
	TRES PATHOLOGIQUE																	
		Statique	Dynamique															
		Equilibre	Coordinations globales	MVTS alternatifs	Contrôle et précision	Vitesse des mouvements	Gnoso Praxies manuelles	Somatognosies	Schéma du Bonhomme	Connaissance du vocabulaire	Orientation	Visuo-construction	Connaissance du temps social	Rythmes	Graphie	Rapidité	Planification	Impulsivité

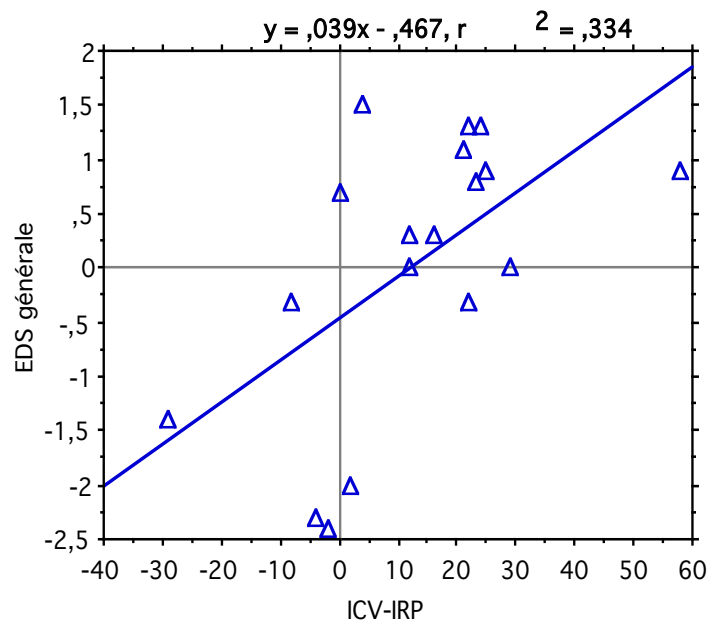




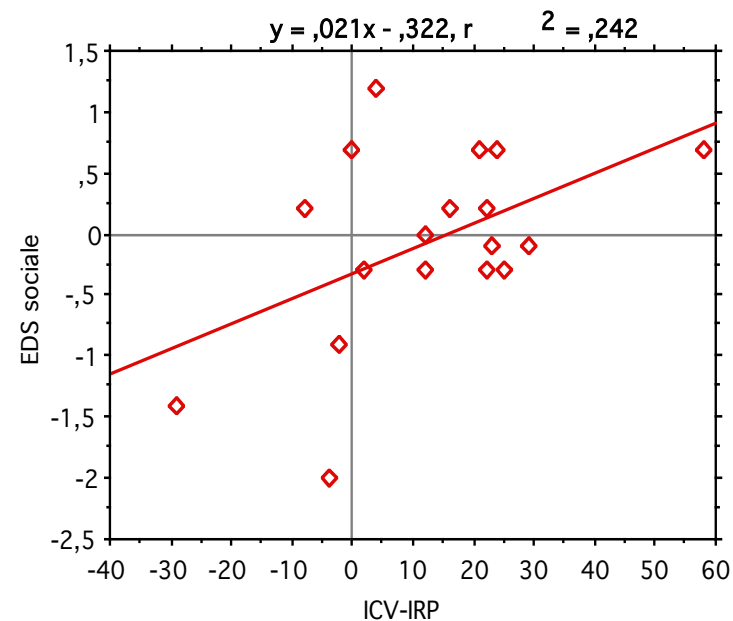
Perfil cognitivo de 20 niños con alto potencial intelectual y fracaso escolar (incluyo 12 con dificultad en lectura )



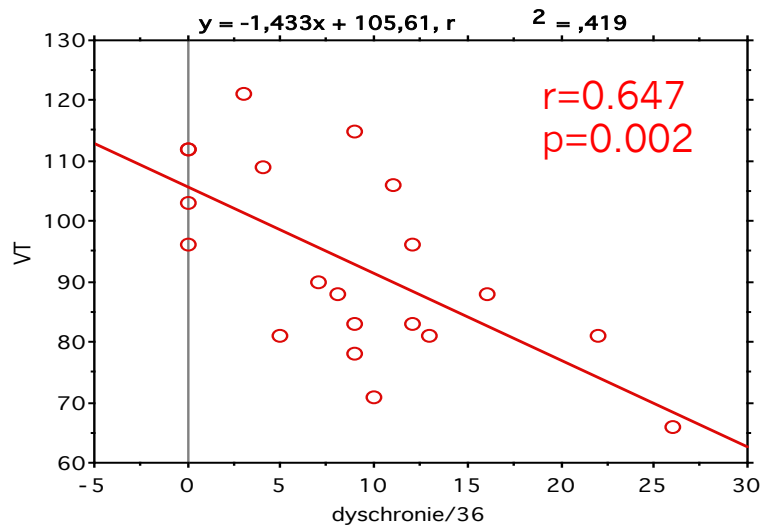
# Corrélation écart verb/non-verb avec estime de soi (questionnaire de Coopersmith)



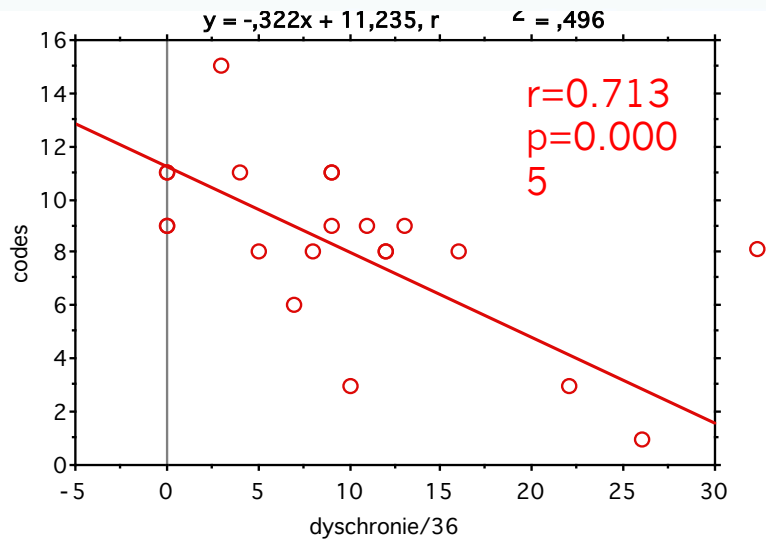
Estime de soi : score global.  
 **$r=0.578$ ,  $p=0.012$**



Estime de soi : score social  
 **$r=0.492$ ,  $p=0.0383$**



corrélation dyschronie / IVT



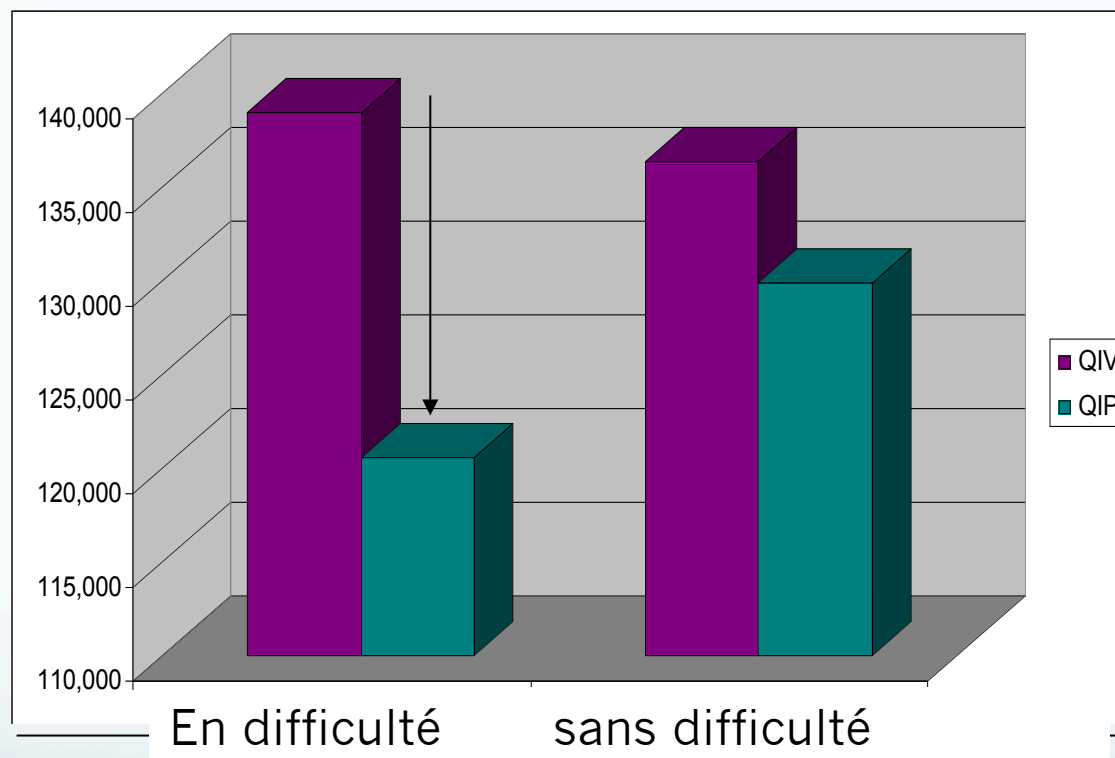
corrélation dyschronie / codes

	Jamais	Rarement	Parfois	Souvent	Très souvent
1- Il (Elle) se souvient difficilement des jours / mois / année que nous sommes.					
2- Il (Elle) confond les moments de la journée matin / après-midi / soirée.					
3- Un événement qui est survenu le matin, il (elle) peut le placer la veille.					
4- Pour un événement qui est survenu il y a quelques jours, il (elle) peut dire : "il y a très longtemps".					
5- Il lui est difficile de comprendre les relations existantes entre les membres de la famille : grands-parents, tantes, neveux, beau-frère.					
6- Il (Elle) a du mal à comprendre les notions de hier, demain ou après-demain.					
7- Il (Elle) a des difficultés à lier l'heure sur un cadran.					
8- Il (Elle) se trompe lorsque il (e)lle doit évaluer la durée d'un film, la durée d'une activité, voire même la durée d'une nuit de sommeil.					
9- Vous avez besoin de lui donner des indices pour qu'il (elle) se repère dans une semaine (lundi : école ; mercredi : activités extra-scolaires ; dimanche : repos ...).					

# Protocole expérimental

- 10 EIP sans troubles d'apprentissage
  - âge : 9;3 a. à 13;9 a,
  - scolarisés entre 6e et 4e;
  - 9 G, 1F.
- 9 EIP avec troubles d'apprentissage
  - âge : 9;4 a. à 13;10 a,
  - scolarisés entre 6e et 3e;
  - 7 G, 2F.
- Analyse du langage oral : TLOCC
- Analyse du langage écrit
  - LMC-R
  - Alouette
  - Odédys
  - Vol du PC
- Épreuve spécifique visuo-attentionnelle : report global de S. Valdois

# Profil du QI de chaque groupe

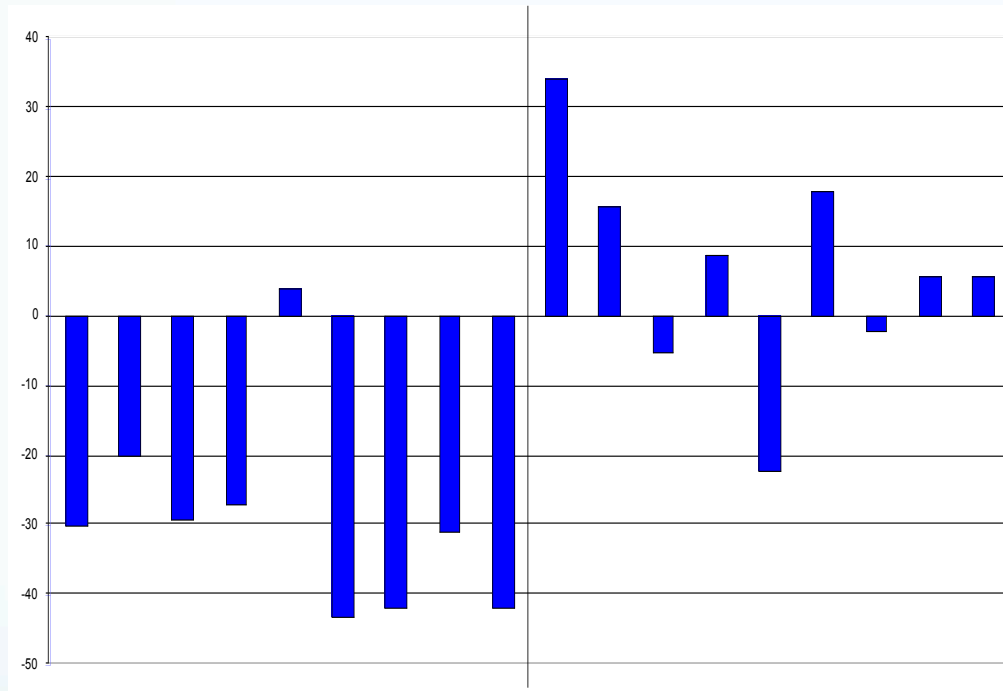


QI verbal > QI non verbal

Ecart plus important pour le groupe d' EIP présentant des troubles des apprentissages



# Âge de lecture (Alouette)



Diff. Apprent.  
- 29 mois

Sans Diff. Apprent.  
+ 7 mois

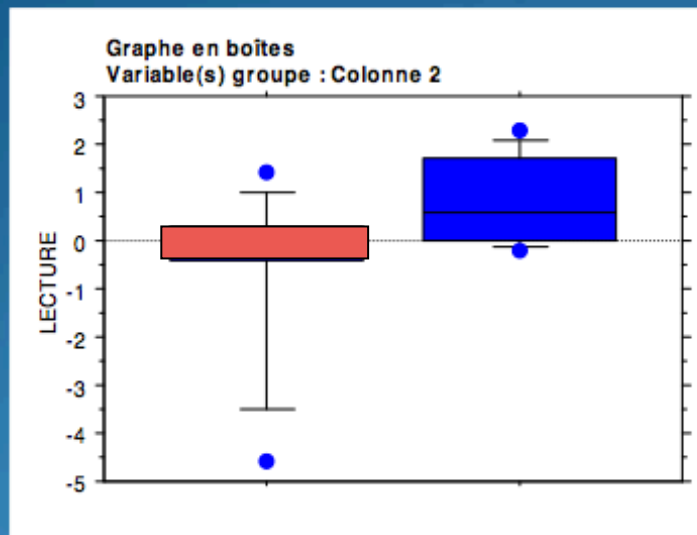
→ 8 dyslexies

→ 1 dyslexie

Groupe avec  
difficultés : tous dysl.  
sauf 1

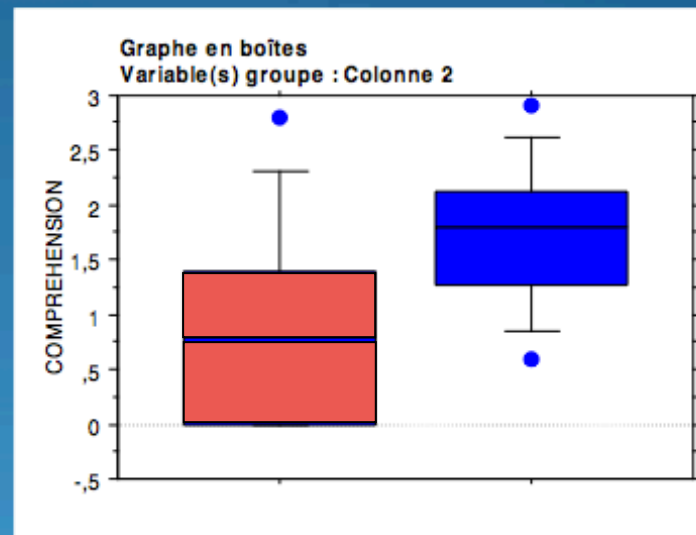
Groupe sans difficulté :  
tous non-dysl. sauf 1

## Lecture de texte



Niveau autour de la moyenne

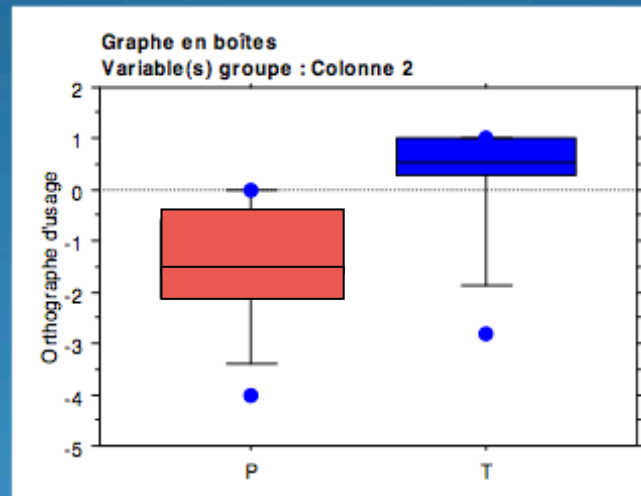
## Compréhension de texte



Bonne compréhension écrite

→ Stratégies de compensation

## Orthographe d'usage



Niveau pathologique pour 7 EIP sur 10

→ 7 dysorthographies de surface

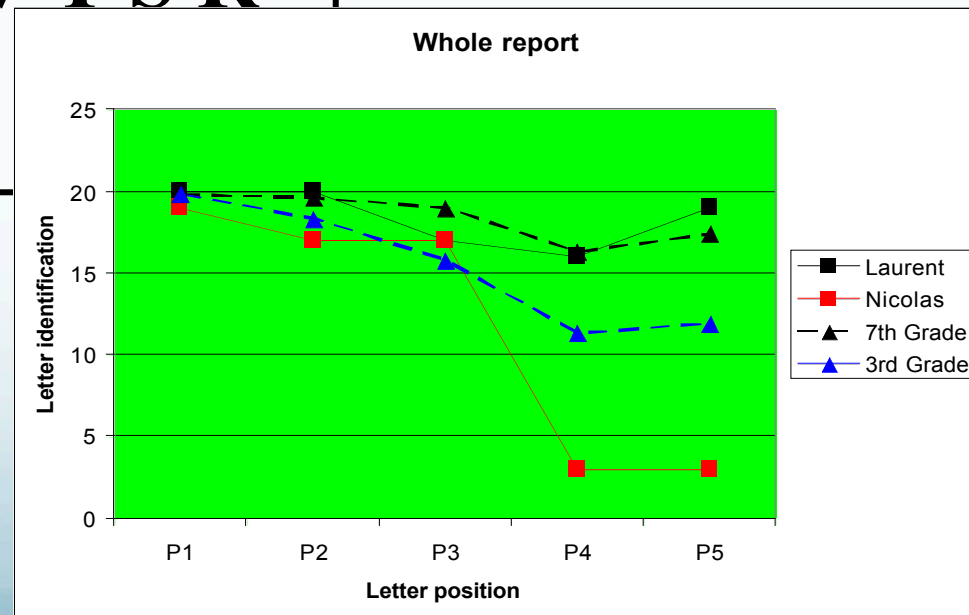
Stock lexical orthographique déficitaire (ex : « assez » → « assé »)

# Epreuve visuo-attentionnelle (S. Valdois)

## Report Global

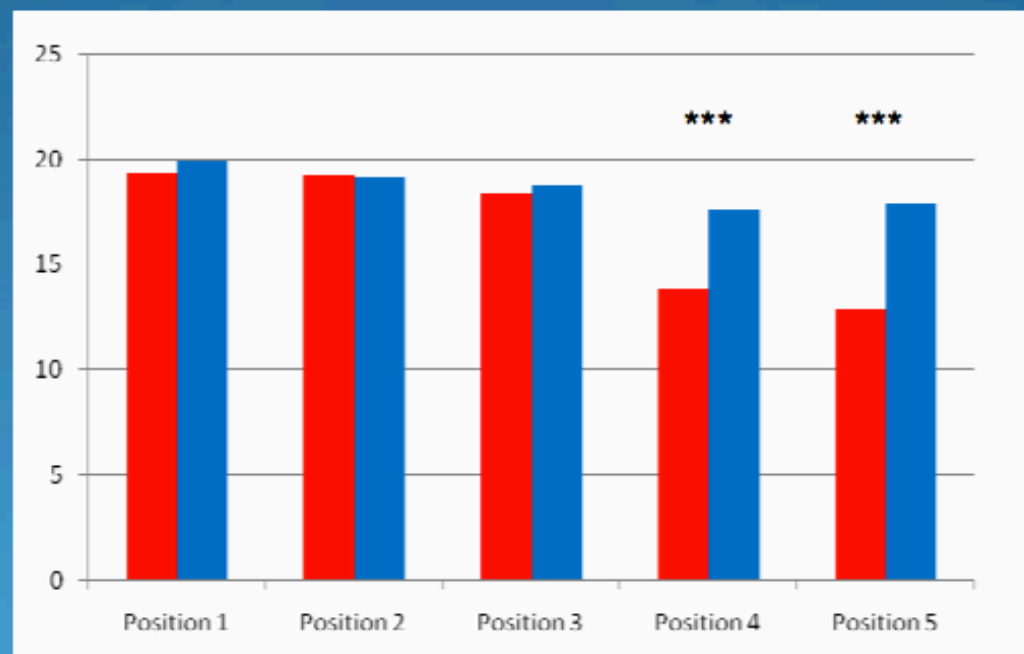
A V T S R

Réponse



## ➤ Compétences visuo-attentionnelles

### Report Global (S.Valdois)



\*\*\*  $p = 0.003$

Effet positionnel → troubles visuo-attentionnels

- EIP avec tr. d'apprentissage
- EIP sans tr. d'apprentissage



# En résumé

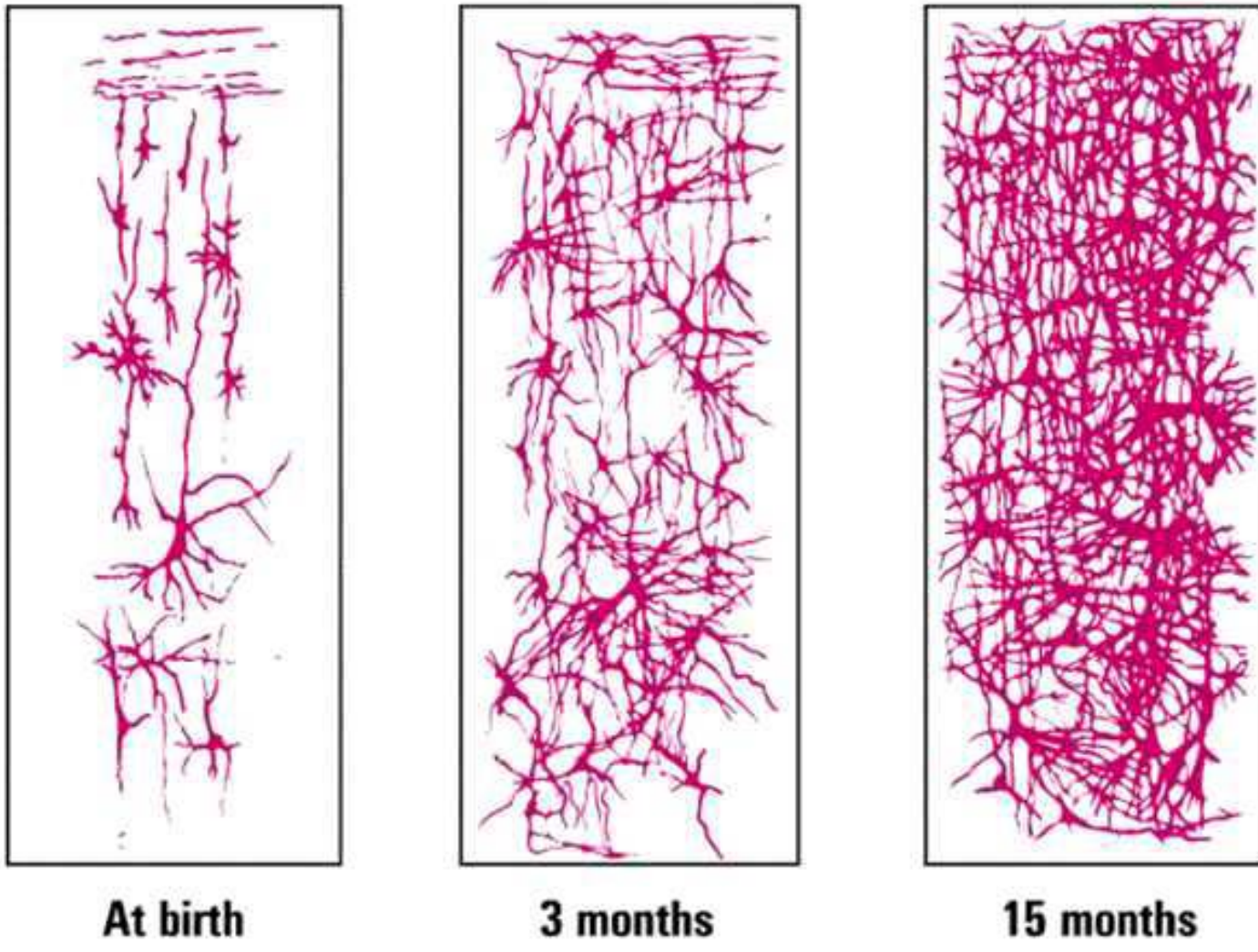
- Les précoces avec difficultés d'apprentissage diffèrent fondamentalement des précoces sans difficultés par la fréquence d'un déficit spécifique d'acquisition de la lecture
- Ce déficit n'est pas nécessairement connu, parce que compensé
- Ils ne diffèrent pas des EIP sans difficultés d'apprentissage sur l'efficacité de la lecture
- Il existe en revanche chez eux une dysorthographe significative
- Le déficit de lecture réalise typiquement un tableau de dyslexie visuo-attentionnelle suggérant une dysfonction spécifique des circuits temporo-pariétaux de l'attention

# Deuxième partie: plasticité cérébrale et rééducation

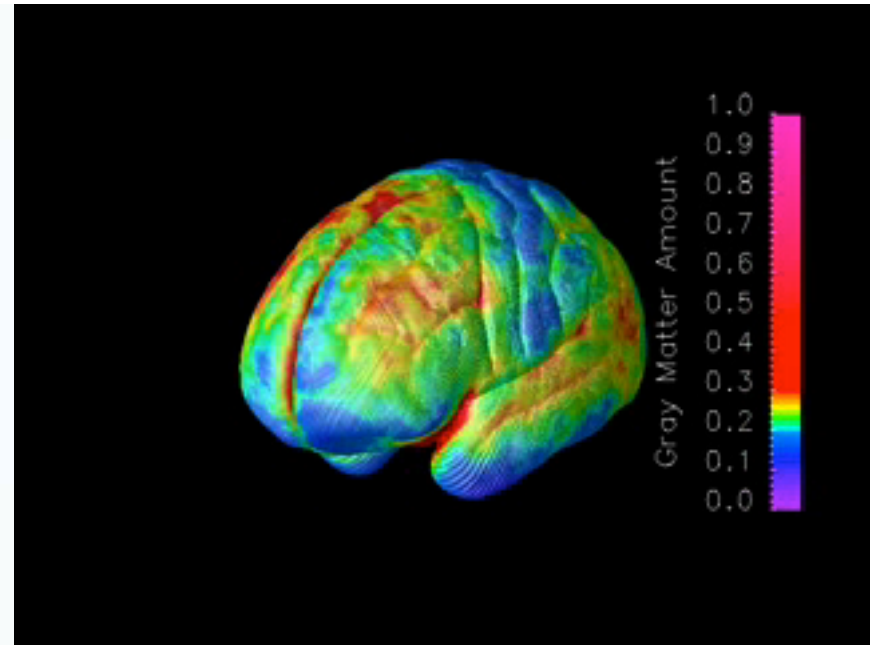
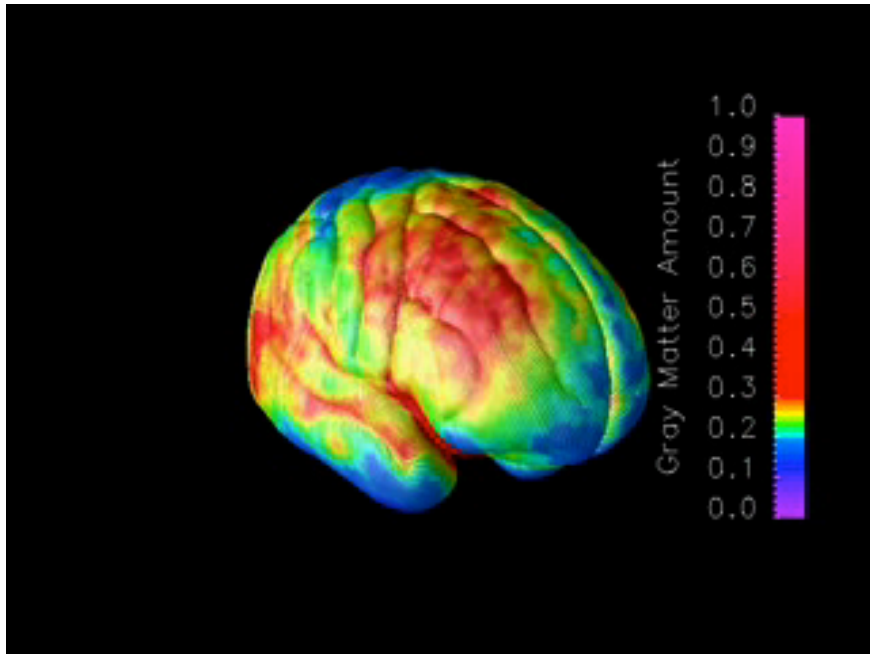
# Plasticité cérébrale : définition

**Plasticité cérébrale** (= neuroplasticité): capacité du système nerveux central (SNC) à modifier sa structure et sa fonction en réponse à des contraintes.....

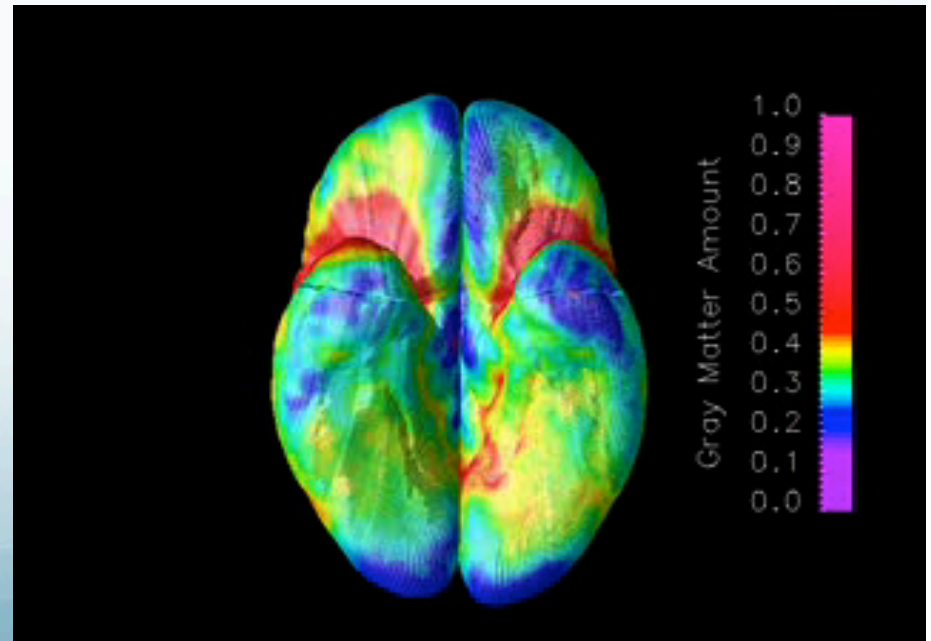
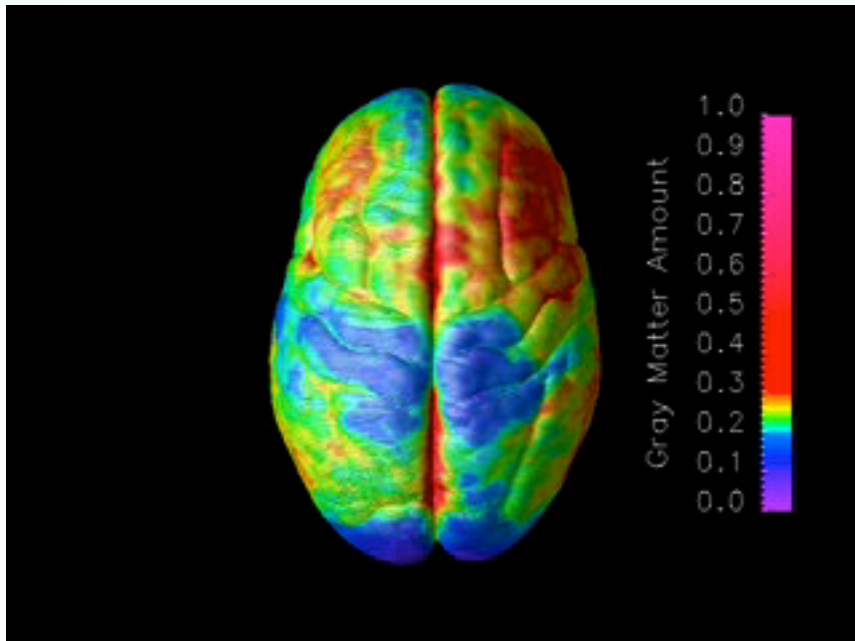
- Internes:
  - développement, maturation, vieillissement
  - expérience
  - atteintes du SNC (lésions).
- Externes:
  - nouvelles acquisitions (entraînement)
  - enrichissement/déprivations sensorielles
  - substances pharmacologiquesetc....et ceci tout au long de la vie
- **Trois types de neuroplasticité** :
  - La neuro-plasticité spontanée au cours du développement
  - **La neuro-plasticité liée à l'entraînement**
  - La neuro-plasticité adaptative post-lésionnelle



Prolifération dendritique : atteint son maximum vers 2 ans : ensuite, perte de milliers de connexions ("pruning"). Vers 16 ans, seulement la moitié des synapses persistent

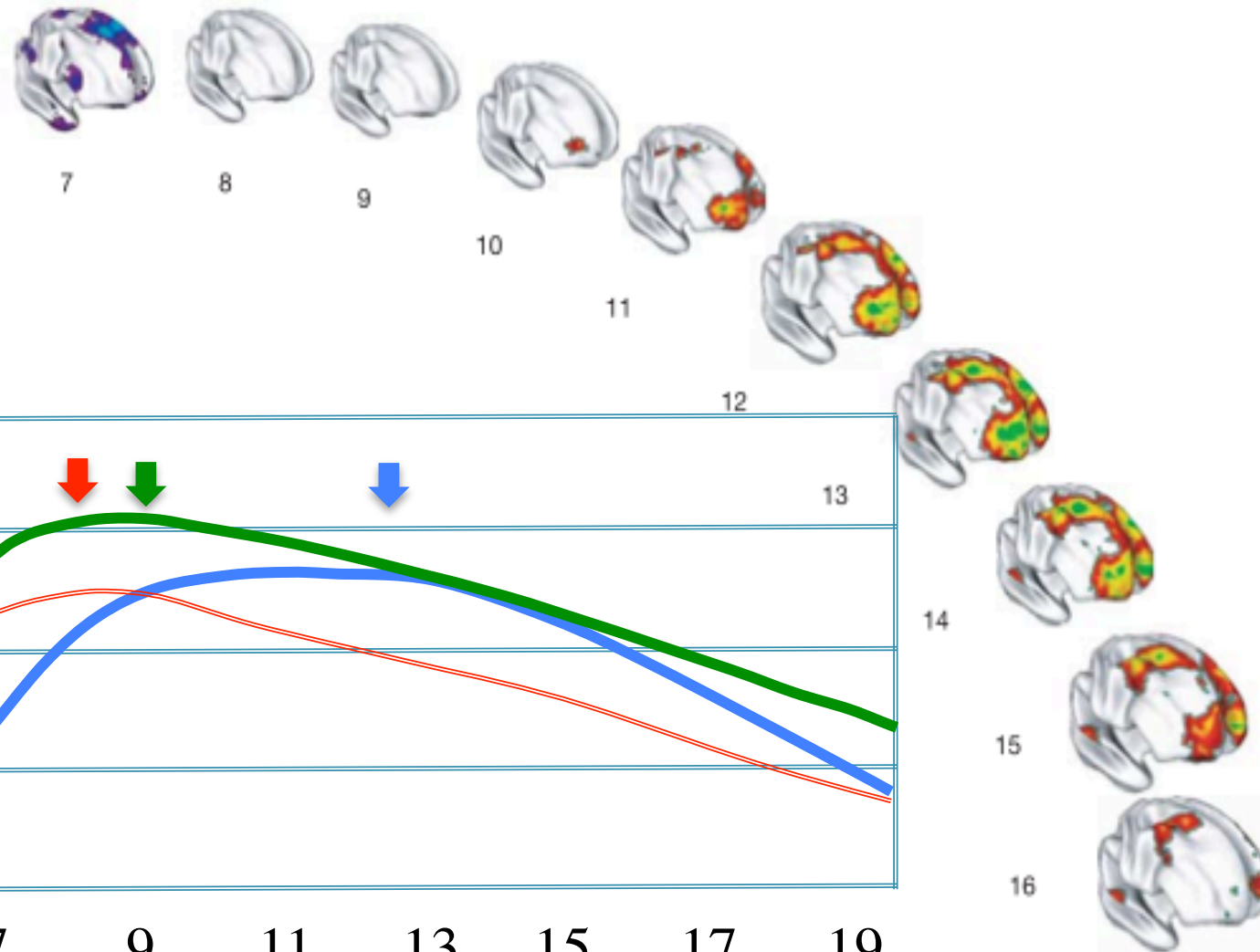


gray matter maturation over the cortical surface between ages 4 and 21 (Gogtay et al. /pnas, 2004)



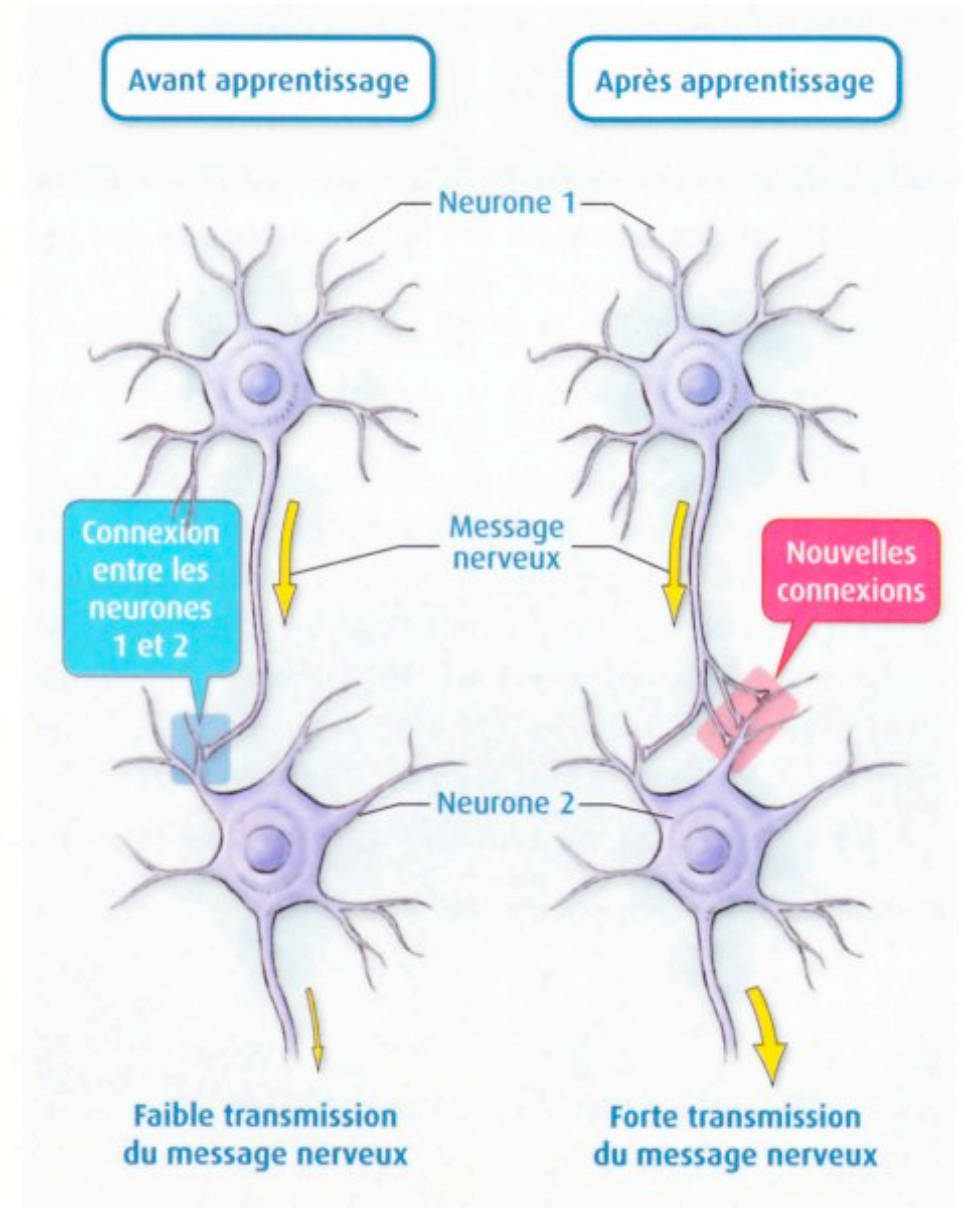
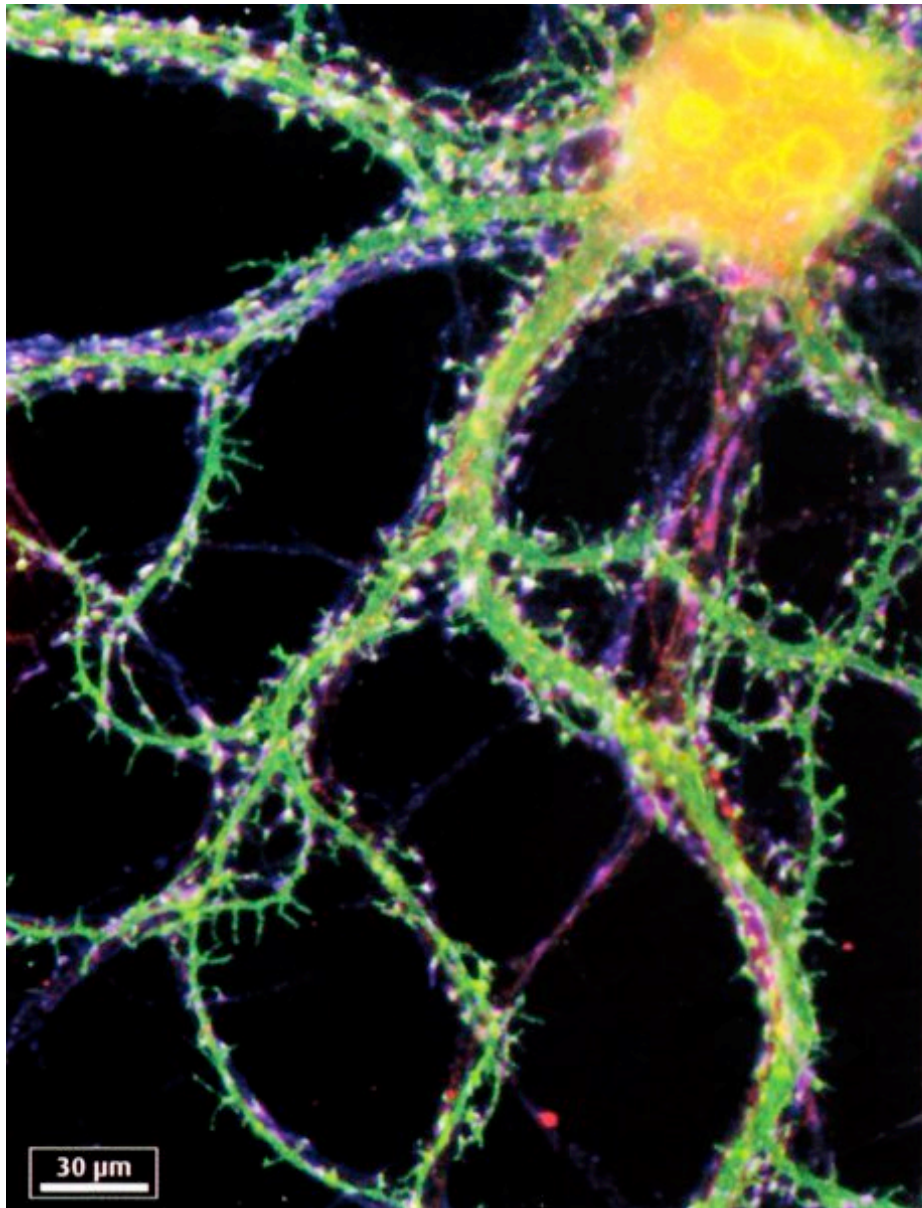


# Épaisseur du cortex et intelligence



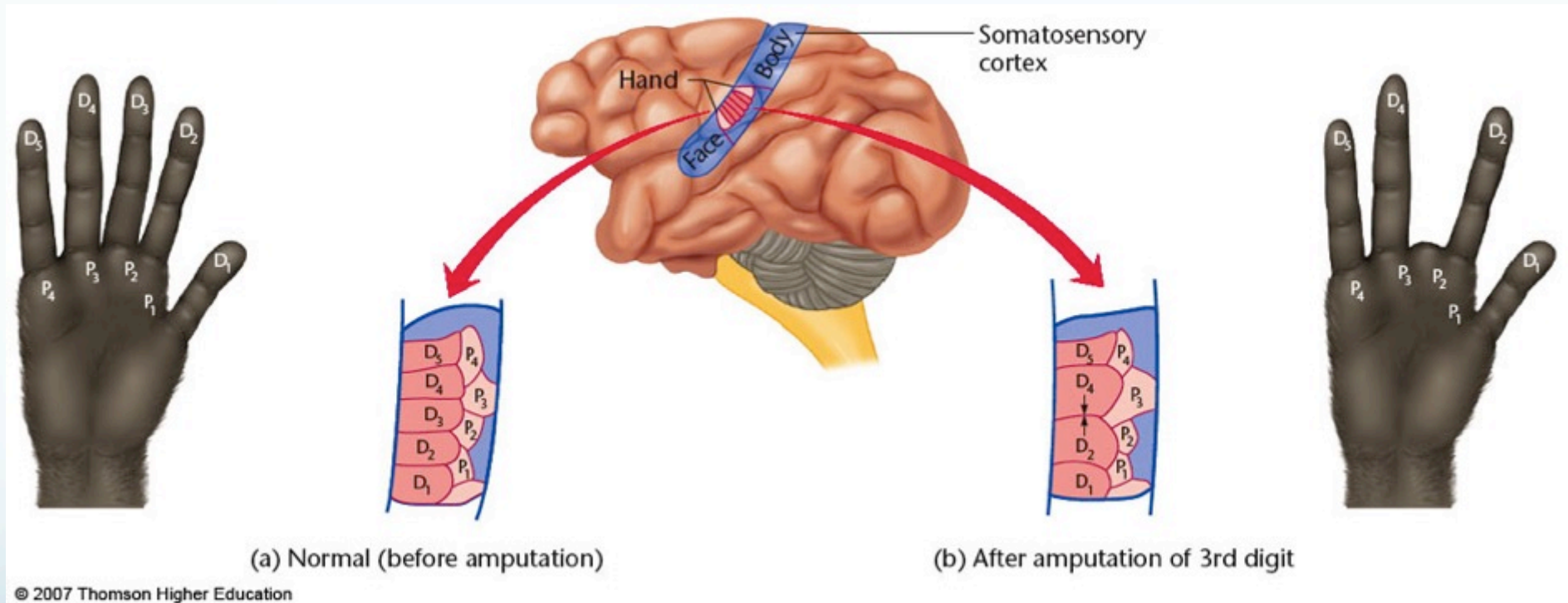
- Intelligence supérieure
- Intelligence haute
- Intelligence moyenne

âge



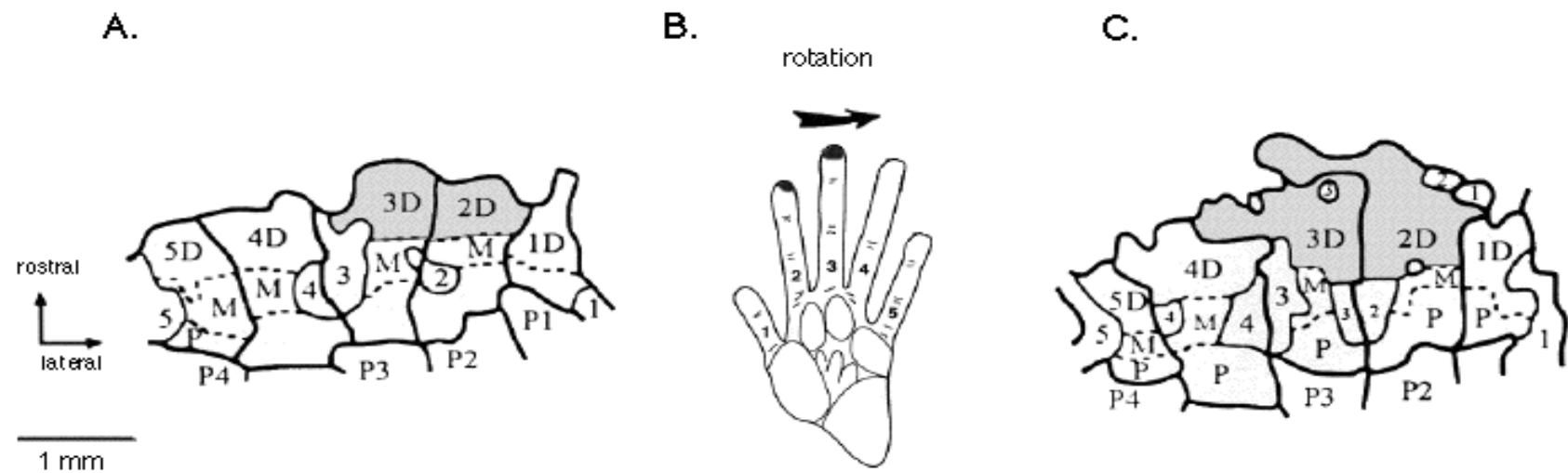
Neuroplasticité et apprentissage : apprendre s'accompagne de modifications structurales du cerveau

# Neuroplasticité liée à l'entraînement



Altérer la fonction modifie le substrat structurel de cette fonction





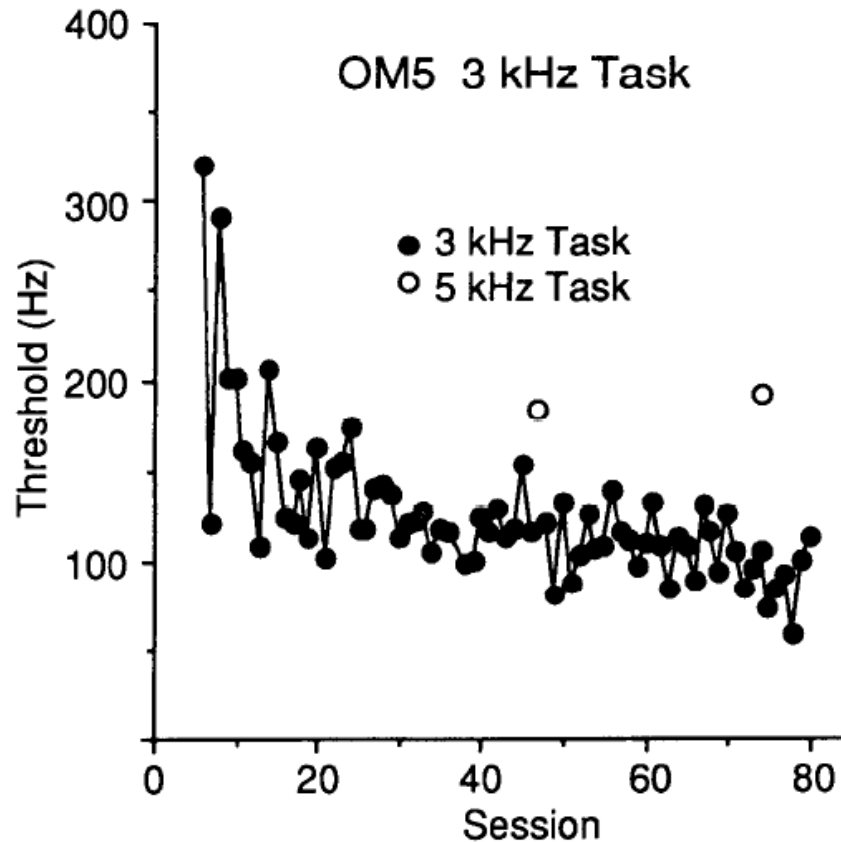
- Daily intensive training with sensory-motor task in monkey modifies brain functional maps (Jenkins et al., 1990)
- A few minutes/day practice is enough to significantly modify cortical surface (Xerri et al., 1999)

## Plasticity in the Frequency Representation of Primary Auditory Cortex following Discrimination Training in Adult Owl Monkeys

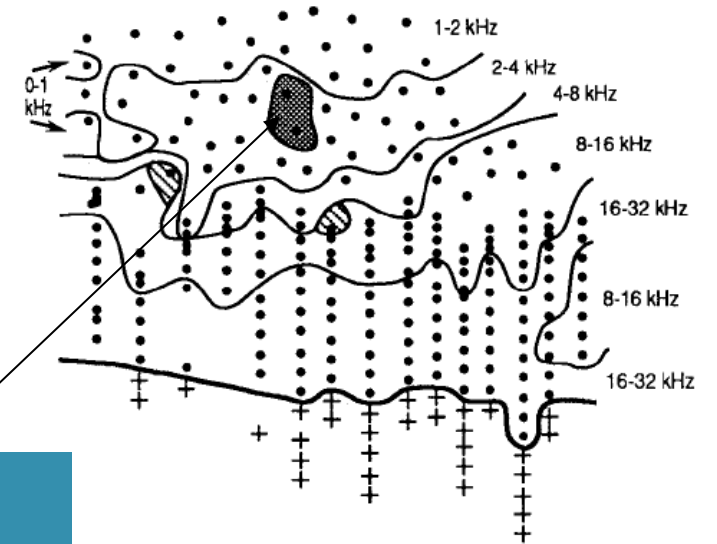
G. H. Recanzone,<sup>1</sup> C. E. Schreiner, and M. M. Merzenich

Coleman Laboratory, Departments of Otolaryngology and Physiology and Keck Center for Integrative Neuroscience, University of California at San Francisco, San Francisco, California 94143-0732

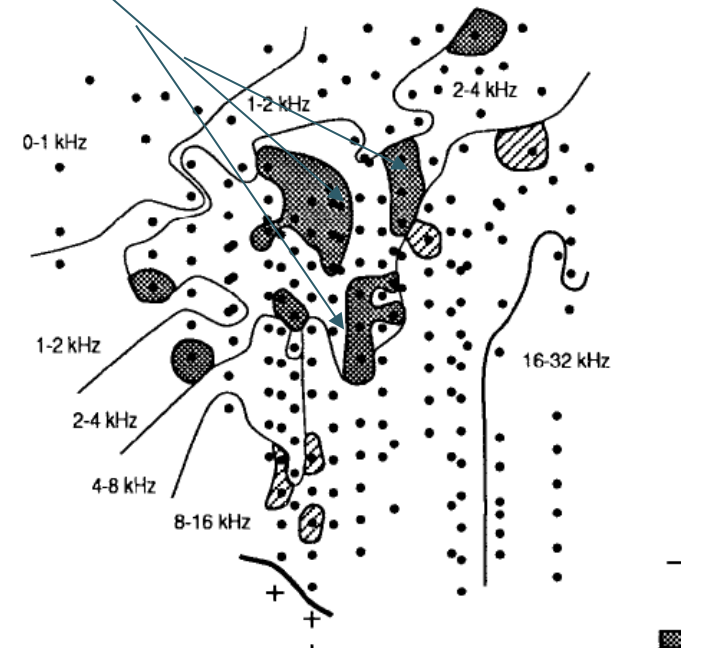
Tonotopic maps in the auditory cortex can also be modified by training specific frequencies



### A Normal Owl Monkey



### B OM3 Trained on 2.5kHz Task



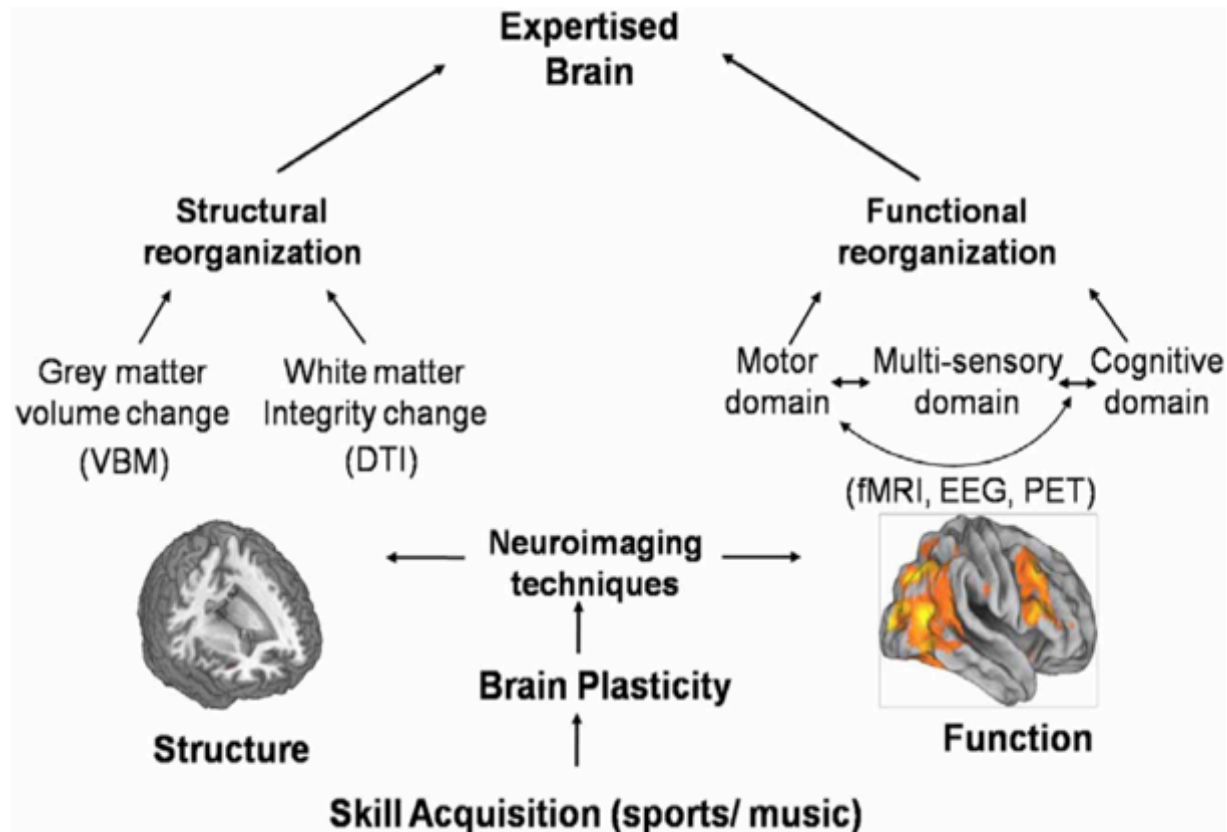




# Reorganization and plastic changes of the human brain associated with skill learning and expertise

**Yongmin Chang\***

*Department of Molecular Medicine and BK21 Plus KNU Biomedical Convergence Program, Kyungpook National University School of Medicine, Daegu, South Korea*



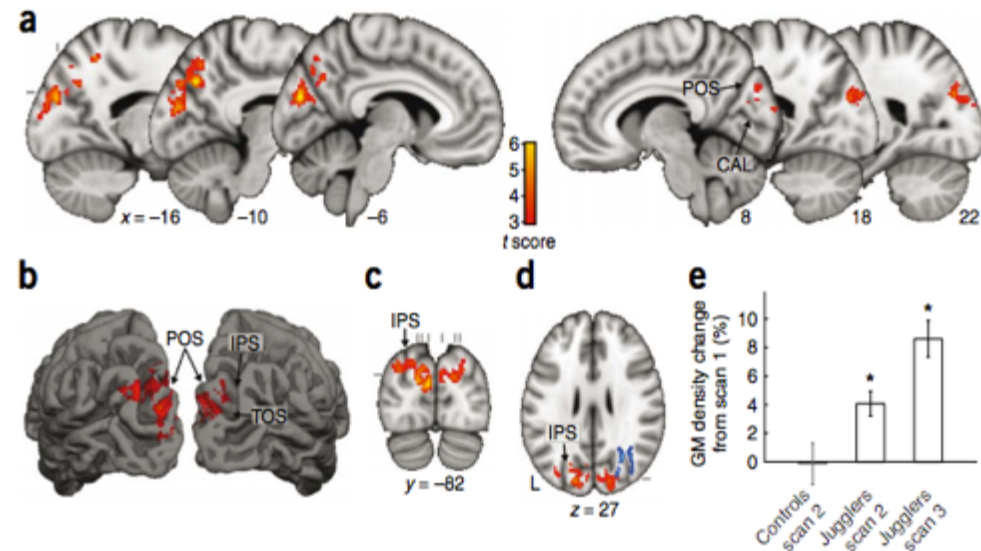
# Plasticité sur le cerveau humain

Jacini et al., 2009	Sports	Cross-sectional	VBM	Judo players showed larger GM volume in frontal and prefrontal cortex
Jäncke et al., 2009	Sports	Cross-sectional	VBM, DTI	Golfers showed Larger GM volumes in premotor and parietal cortices; smaller FA along the internal and external capsule and the parietal operculum
Di Paola et al., 2013	Sports	Cross-sectional	VBM	Mountain climbers showed significantly larger vermian lobule volumes
Draganski et al., 2004	Sports	Longitudinal	VBM	Three months' juggling practice-induced GM expansion in mid-temporal area (visual) and posterior intraparietal sulcus (spatial), followed by a decreased to baseline levels after 3 months with no practice
Bezzola et al., 2011	Sports	Longitudinal	VBM	Forty hours of golf training showed an association with gray matter increases in a task-relevant cortical network
Amunts et al., 1997	Music	Cross-sectional	MRI	Hand motor area was larger in professional musicians than in non-musicians
Gaser and Schlaug, 2003	Music	Cross-sectional	VBM	GM volume differences in sensorimotor cortex, premotor cortex, and cerebellum
Han et al., 2009	Music	Longitudinal	DBM	Fifteen months of musical training in early childhood showed structural change in brain

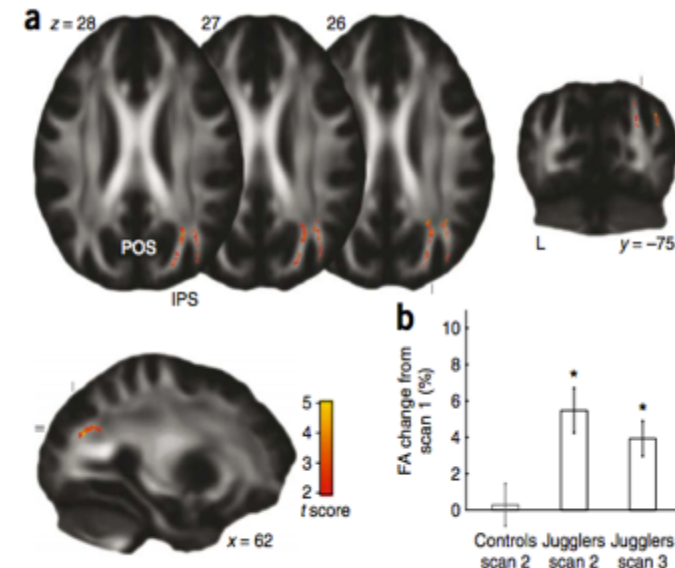
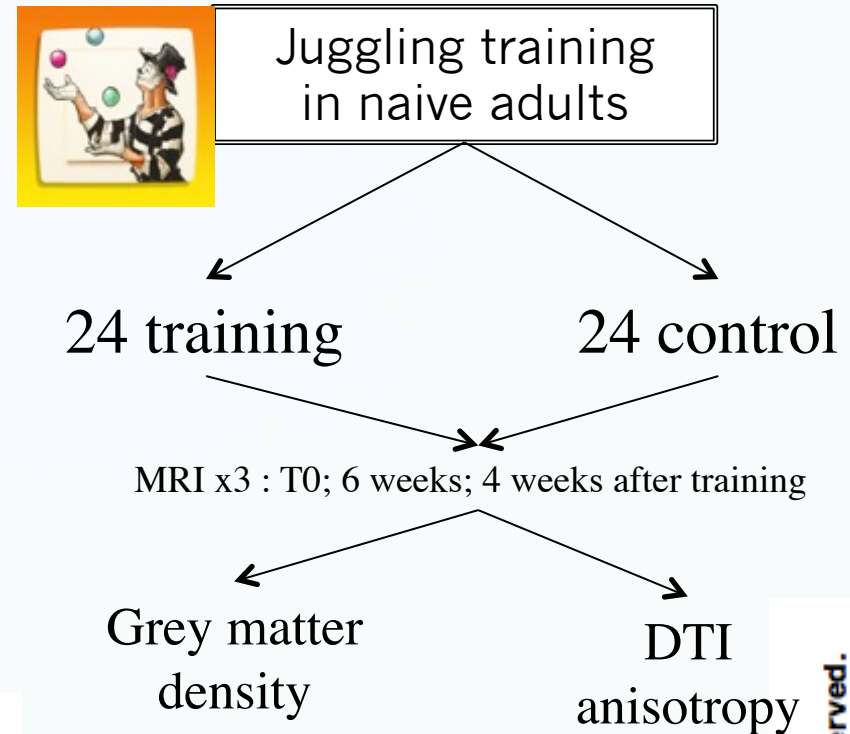
# Training induces changes in white-matter architecture

Jan Scholz<sup>1</sup>, Miriam C Klein<sup>1,2</sup>, Timothy E J Behrens<sup>1,2</sup> & Heidi Johansen-Berg<sup>1</sup>

Although experience-dependent structural changes have been found in adult gray matter, there is little evidence for such changes in white matter. Using diffusion imaging, we detected a localized increase in fractional anisotropy, a measure of microstructure, in white matter underlying the intraparietal sulcus following training of a complex visuo-motor skill. This provides, to the best of our knowledge, the first evidence for training-related changes in white-matter structure in the healthy human adult brain.



**Figure 2** Gray-matter density increases after juggling training. (a-d) Red and yellow voxels represent clusters ( $P < 0.05$ , corrected) of significant gray-matter density increase from scan 1 to scan 2,



**Figure 1** Fractional anisotropy increases after juggling training.



# Structural changes in left fusiform areas and associated fiber connections in children with abacus training: evidence from morphometry and tractography

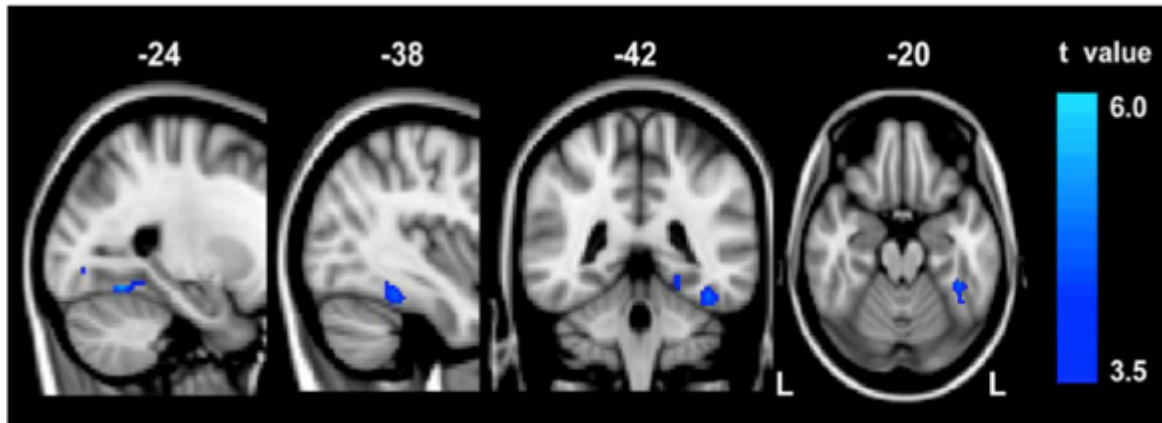
Yongxin Li<sup>1</sup>, Yunqi Wang<sup>2,3</sup>, Yuzheng Hu<sup>1</sup>, Yurong Liang<sup>4</sup> and Feiyan Chen<sup>1\*</sup>

<sup>1</sup> Bio-X Laboratory, Department of Physics, Zhejiang University, Hangzhou, P. R. China

<sup>2</sup> School of International Studies, Zhejiang University, Hangzhou, P. R. China

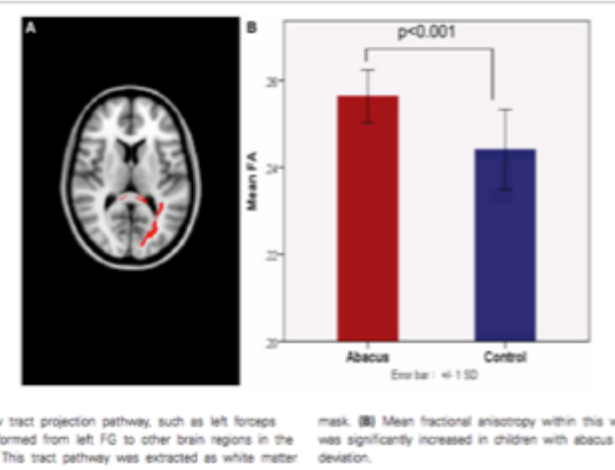
<sup>3</sup> Department of Psychology and Behavioral Sciences, Zhejiang University, Hangzhou, P. R. China

<sup>4</sup> Heilongjiang Abacus Association, Haerbin, P. R. China



1°) Decreased GM in left

2°) Increased WM FA in left forceps major



v tract projection pathway, such as left forceps major. (B) Mean fractional anisotropy within this white matter tract was significantly increased in children with abacus training. This tract pathway was extracted as white matter mask. Error bars = 1 SD.

3°) significant negative correlation was found in the GM volume in left FG and FA value in left forceps major

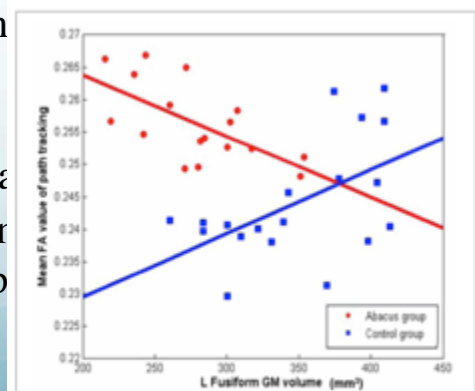
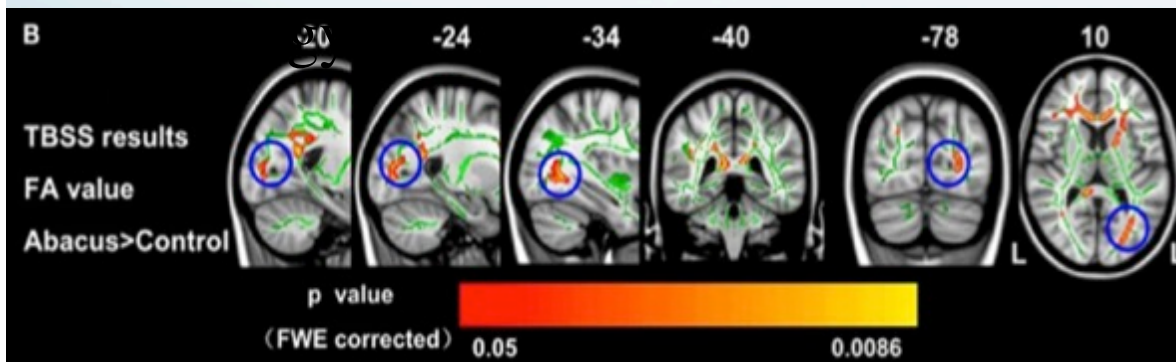


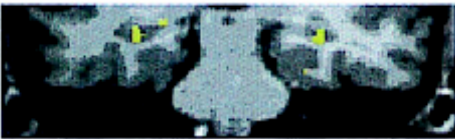
FIGURE 4 | The correlation between the mean FA value of left forceps major tracts and the GM volume in left FG. Mean FA values extracted

# Navigation-related structural change in the hippocampi of taxi drivers

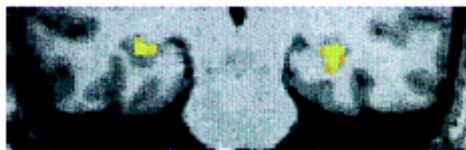
Eleanor A. Maguire<sup>\*†</sup>, David G. Gadian<sup>‡</sup>, Ingrid S. Johnsrude<sup>†</sup>, Catriona D. Good<sup>†</sup>, John Ashburner<sup>†</sup>, Richard S. J. Frackowiak<sup>†</sup>, and Christopher D. Frith<sup>†</sup>

<sup>†</sup>Wellcome Department of Cognitive Neurology, Institute of Neurology, University College London, Queen Square, London WC1N 3BG, United Kingdom; and <sup>‡</sup>Radiology and Physics Unit, Institute of Child Health, University College London, London WC1N 1EH, United Kingdom

Communicated by Brenda Milner, McGill University, Montreal, Canada, January 28, 2000 (received for review November 10, 1999)



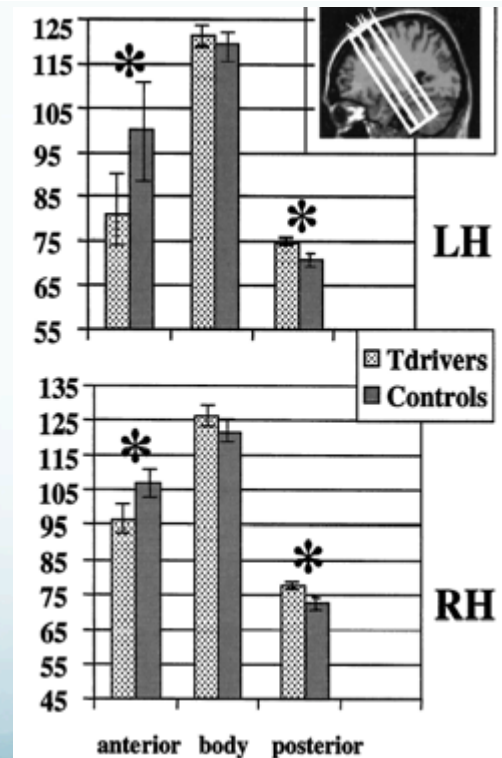
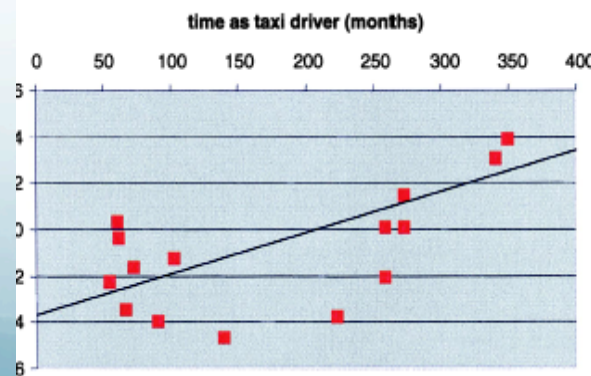
y = -33



y = -27

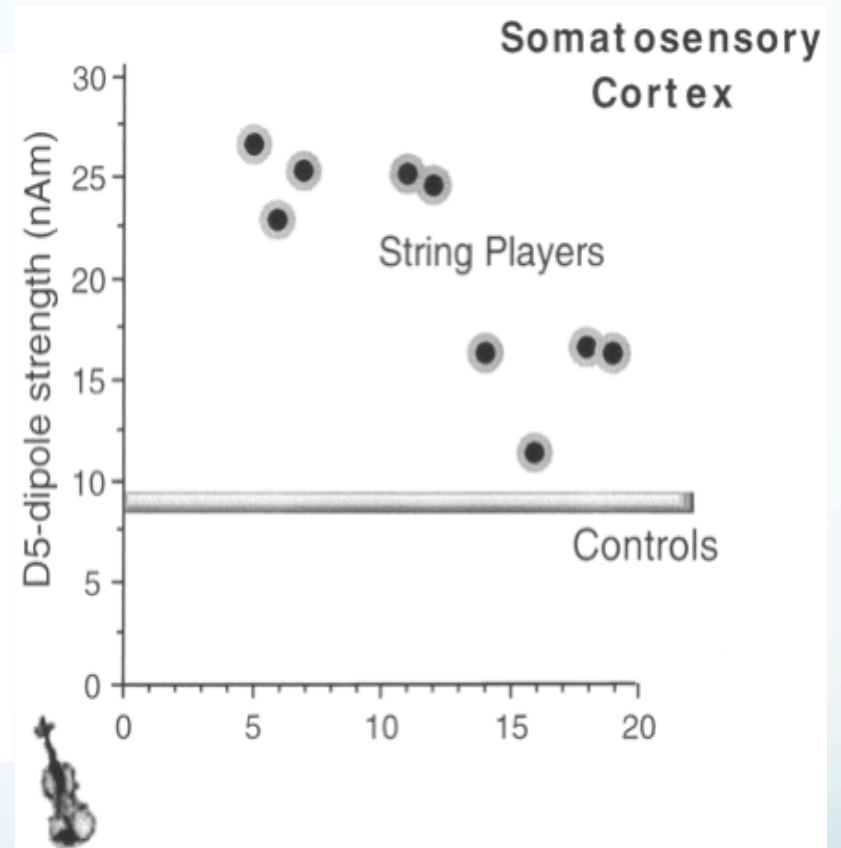
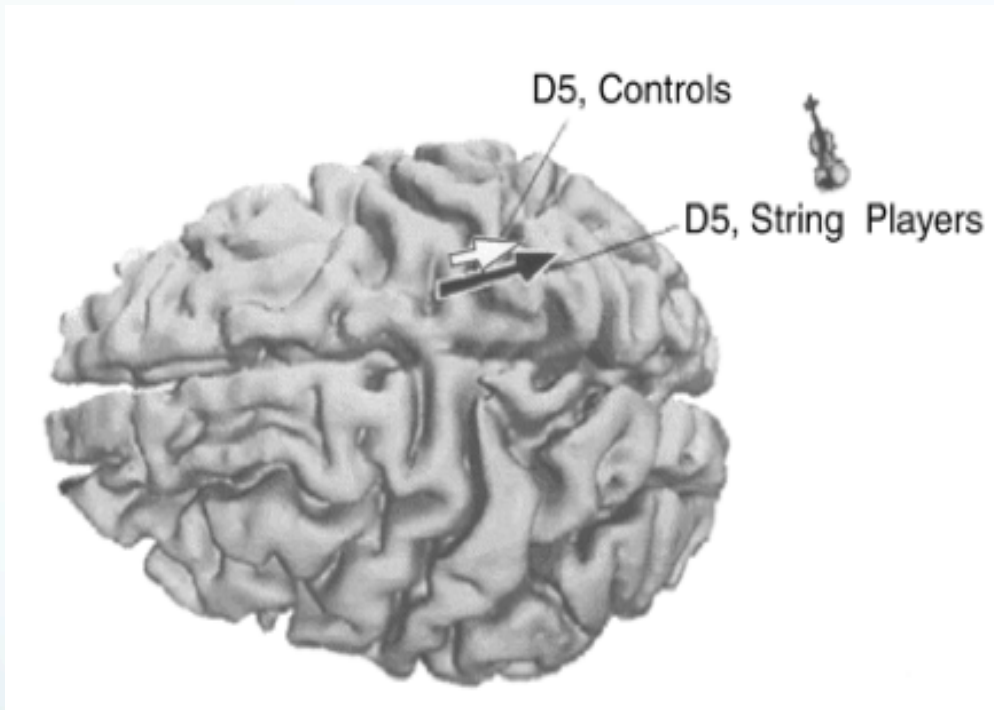


Zones de plus forte densité de pixels chez les chauffeurs de taxi



redistribution relative de matière grise chez





Left hand fifth finger in string instrument players (MEG study, Elbert et al., 1998). Larger dipole in right somatosensory area. Effect of learning age.

# Effects of Music Training on the Child's Brain and Cognitive Development

GOTTFRIED SCHLAUG,<sup>a</sup> ANDREA NORTON,<sup>a</sup> KATIE OVERY,<sup>a</sup> AND ELLEN WINNER<sup>b</sup>

<sup>a</sup>Department of Neurology, Music and Neuroimaging Laboratory, Beth Israel Deaconess Medical Center/Harvard Medical School, Boston, Massachusetts 02215, USA

<sup>b</sup>Department of Psychology, Boston College, Boston, Massachusetts 02215, USA

professional keyboard players, who reported approximately twice as much weekly practice time as the amateur musicians, have significantly more gray matter in several brain regions, including the primary sensorimotor cortex, the adjacent superior premotor and anterior superior parietal cortex bilaterally, mesial Heschl's gyrus (primary auditory cortex), the cerebellum, the inferior frontal gyrus, and part of the lateral inferior temporal lobe, than either the amateur musicians or the nonmusicians.

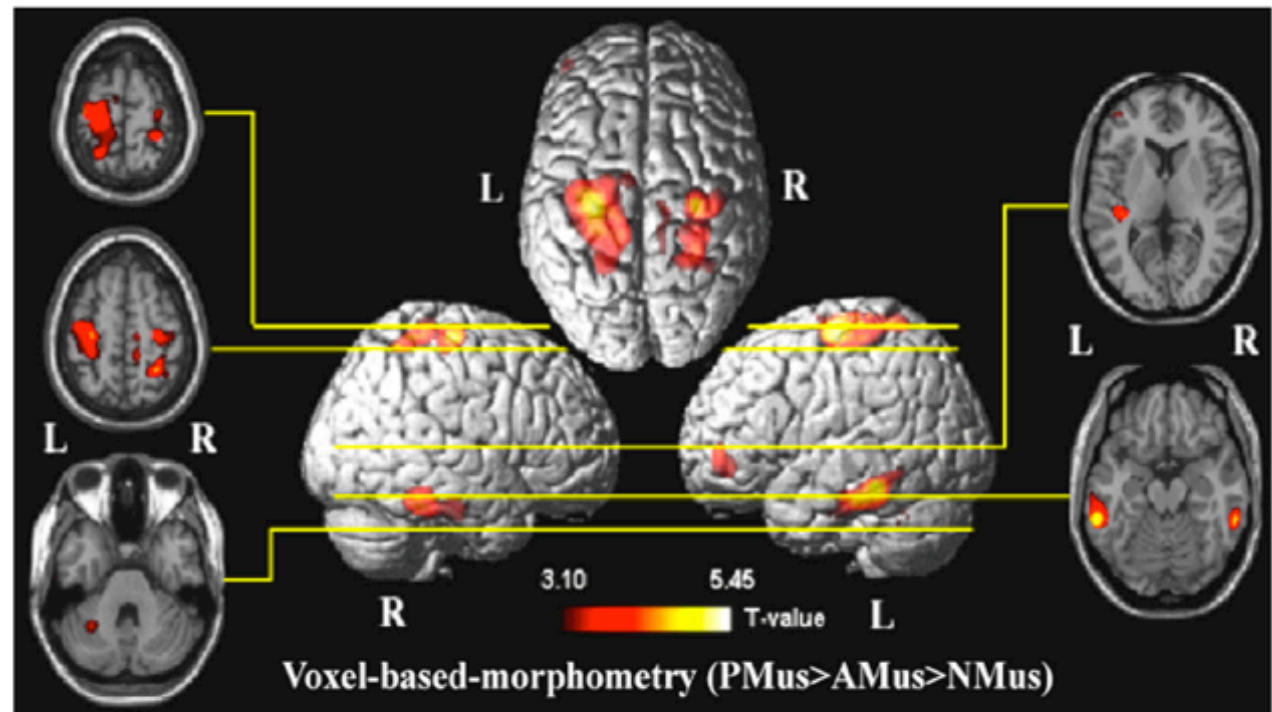
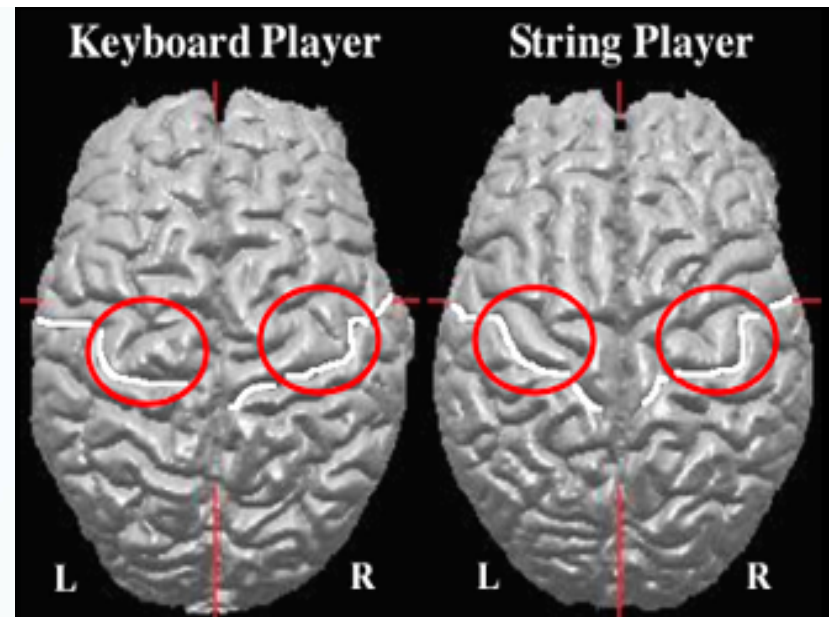
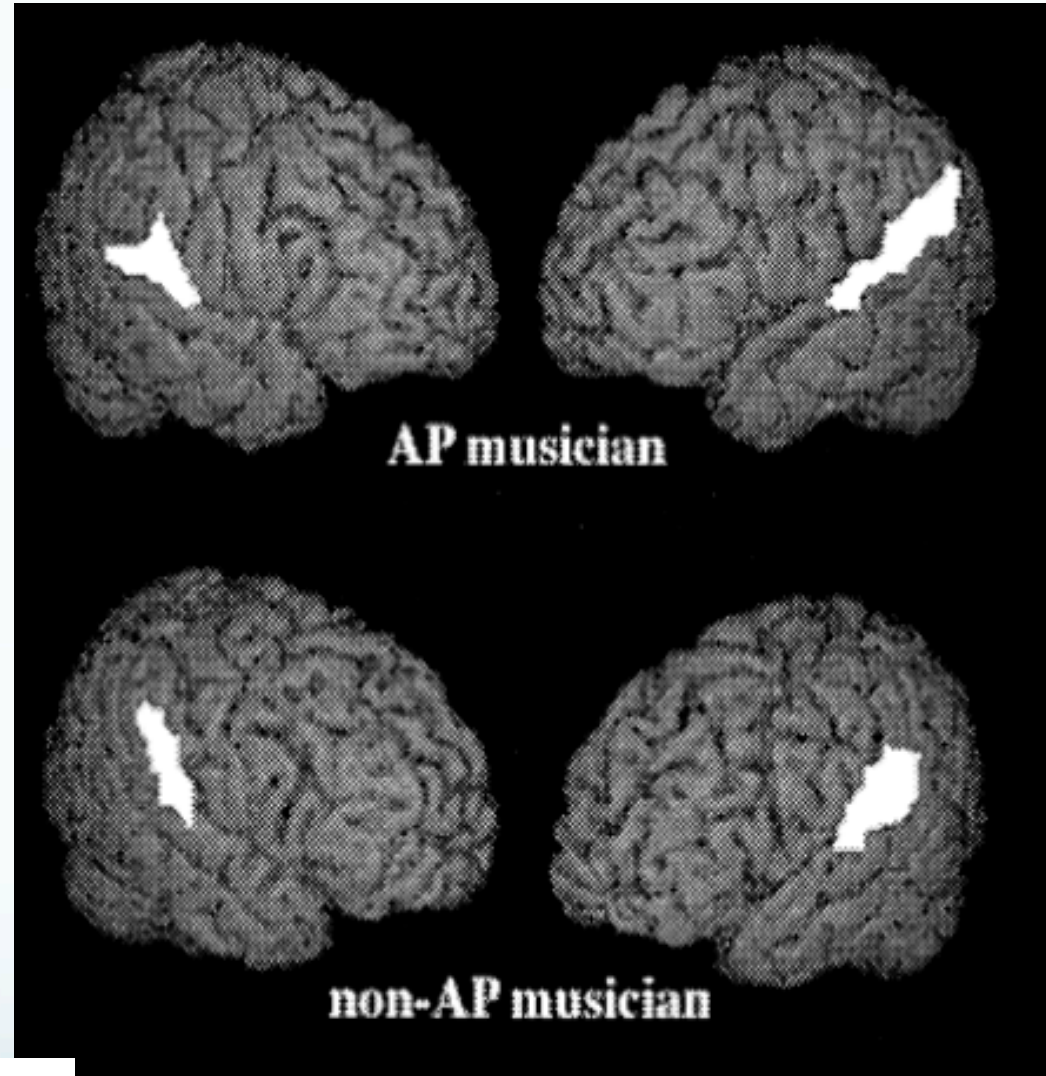


FIGURE 1. A voxel-based morphometric analysis of nonmusicians compared with amateur and professional musicians.

Planum asymmetry is larger in musicians with absolute pitch (AP)

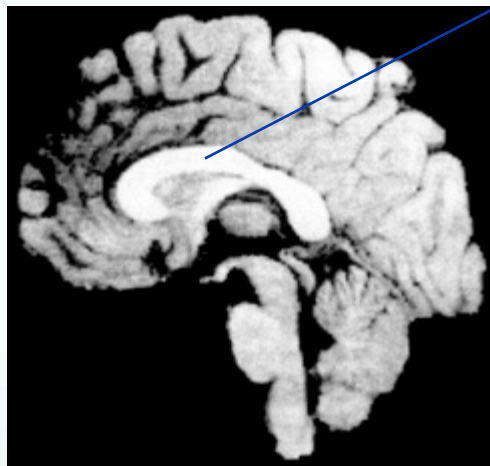


Subject	$\delta$ PT	PT size (mm <sup>2</sup> )	
		Left	Right
AP musicians ( <i>n</i> = 27)	-0.50 (0.27) <sup>a</sup>	1381 (449)	822 (236)
Non-AP musicians ( <i>n</i> = 24)	-0.24 (0.14)	1350 (340)	1062 (267)
Nonmusicians ( <i>n</i> = 27)	-0.28 (0.24)	1341 (306)	008 (285)

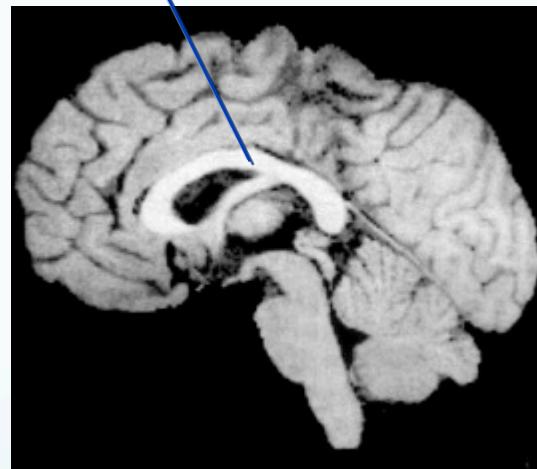
<sup>a</sup>Significant differences between AP musicians and non-AP musicians as well as between AP-musicians and nonmusicians.

GOTTFRIED SCHLAUG  
 The Brain of Musicians: A Model for Functional and Structural Adaptation  
 Ann NY Acad Sci 2001 930: 281-299.

Anterior part of the callosum is larger in early-trained musicians



**MUSICIAN**



**NON- MUSICIAN**

(Schlaug et al., 1995)

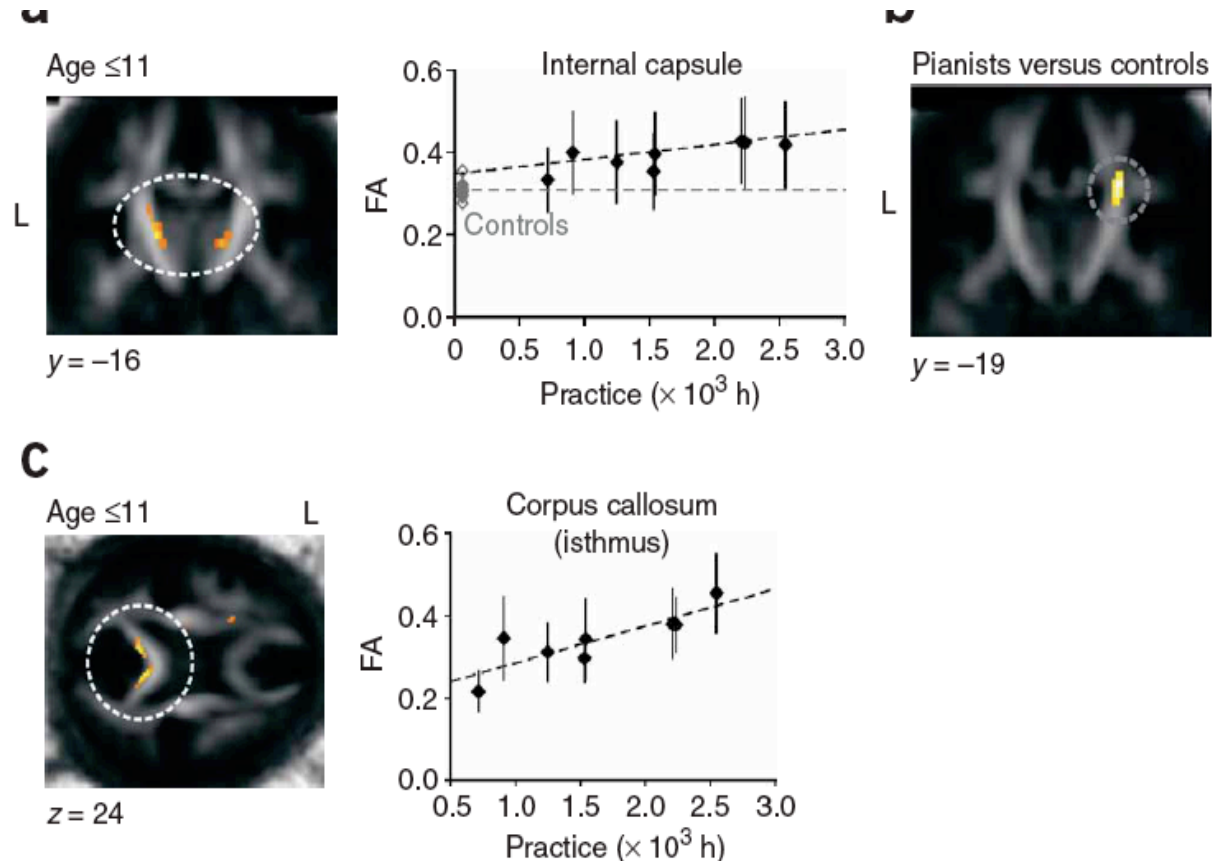


# Extensive piano practicing has regionally specific effects on white matter development

Sara L Bengtsson<sup>1</sup>, Zoltán Nagy<sup>1,2</sup>, Stefan Skare<sup>2</sup>, Lea Forsman<sup>1</sup>, Hans Forsberg<sup>1</sup> & Fredrik Ullén<sup>1</sup>

Using diffusion tensor imaging, we investigated effects of piano practicing in childhood, adolescence and adulthood on white matter, and found positive correlations between practicing and fiber tract organization in different regions for each age period. For childhood, practicing correlations were extensive and included the pyramidal tract, which was more structured in pianists than in non-musicians. Long-term training within critical developmental periods may thus induce regionally specific plasticity in myelinating tracts.

VOLUME 8 | NUMBER 9 | SEPTEMBER 2005 NATURE NEUROSCIENCE





# The Effects of Musical Training on Structural Brain Development

## A Longitudinal Study

Krista L. Hyde,<sup>a</sup> Jason Lerch,<sup>b</sup> Andrea Norton,<sup>c</sup>  
 Marie Forgeard,<sup>c</sup> Ellen Winner,<sup>d</sup> Alan C. Evans,<sup>a</sup>  
 and Gottfried Schlaug<sup>c</sup>

<sup>a</sup>Montreal Neurological Institute, McGill University, Montreal, Quebec, Canada

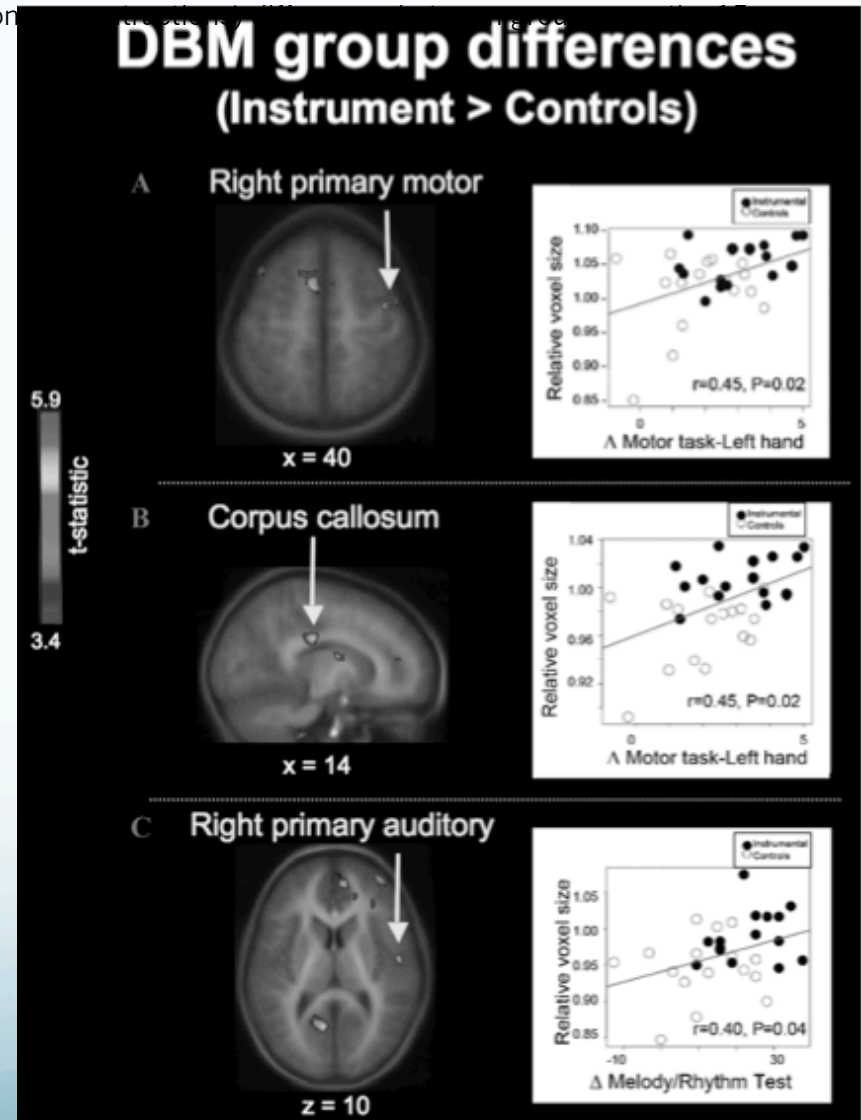
<sup>b</sup>Mouse Imaging Centre, Hospital for Sick Children, Toronto, Ontario, Canada

<sup>c</sup>Department of Neurology, Music and Neuroimaging Laboratory, Beth Israel Deaconess Medical Center and Harvard Medical School, Boston, Massachusetts, USA

<sup>d</sup>Department of Psychology, Boston College, Chestnut Hill, Massachusetts, USA

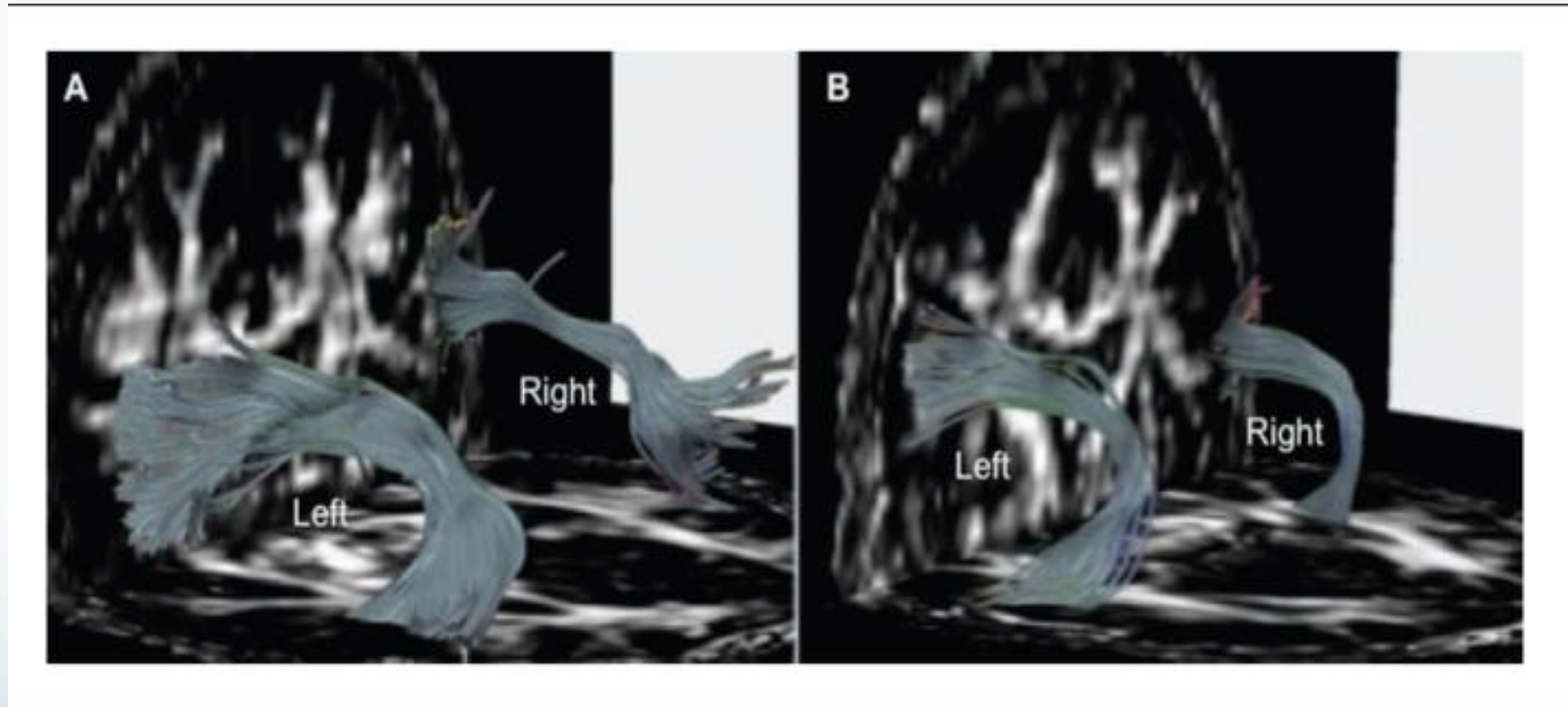
As predicted, Instrumental children showed greater behavioral improvements over the 15 months on the finger motor task and the melody/rhythmic tasks, but not on the non-musical tasks. In addition, Instrumental children showed areas of greater relative voxel size change over the 15 months as compared to Controls in motor brain areas, such as the **right precentral gyrus** (motor hand area, Fig. 1A), and the **corpus callosum** (4th and 5th segment/midbody, Fig. 1B), as well as in a **right primary auditory region** (Heschl's gyrus, Fig. 1C). These brain deformation differences are consistent with structural brain differences found between adult musicians and nonmusicians in the precentral gyri,<sup>2</sup> the corpus callosum,<sup>20-22</sup> and auditory cortex.<sup>2,4,23</sup>

We investigated structural brain changes in relation to behavioral changes in young children (15 mean age at start of study: 6.32 years old) who received 15 months of keyboard training relative to 16 children who did not receive any instrumental music training during this 15-month period, but did participate in a weekly group music class in school (i.e., singing and drums). We used deformation-based morphometry (DBM), an unbiased and automated approach to brain morphology, to search throughout the whole brain on a voxel-wise basis for local brain size (voxel expansion) over the 15 months.



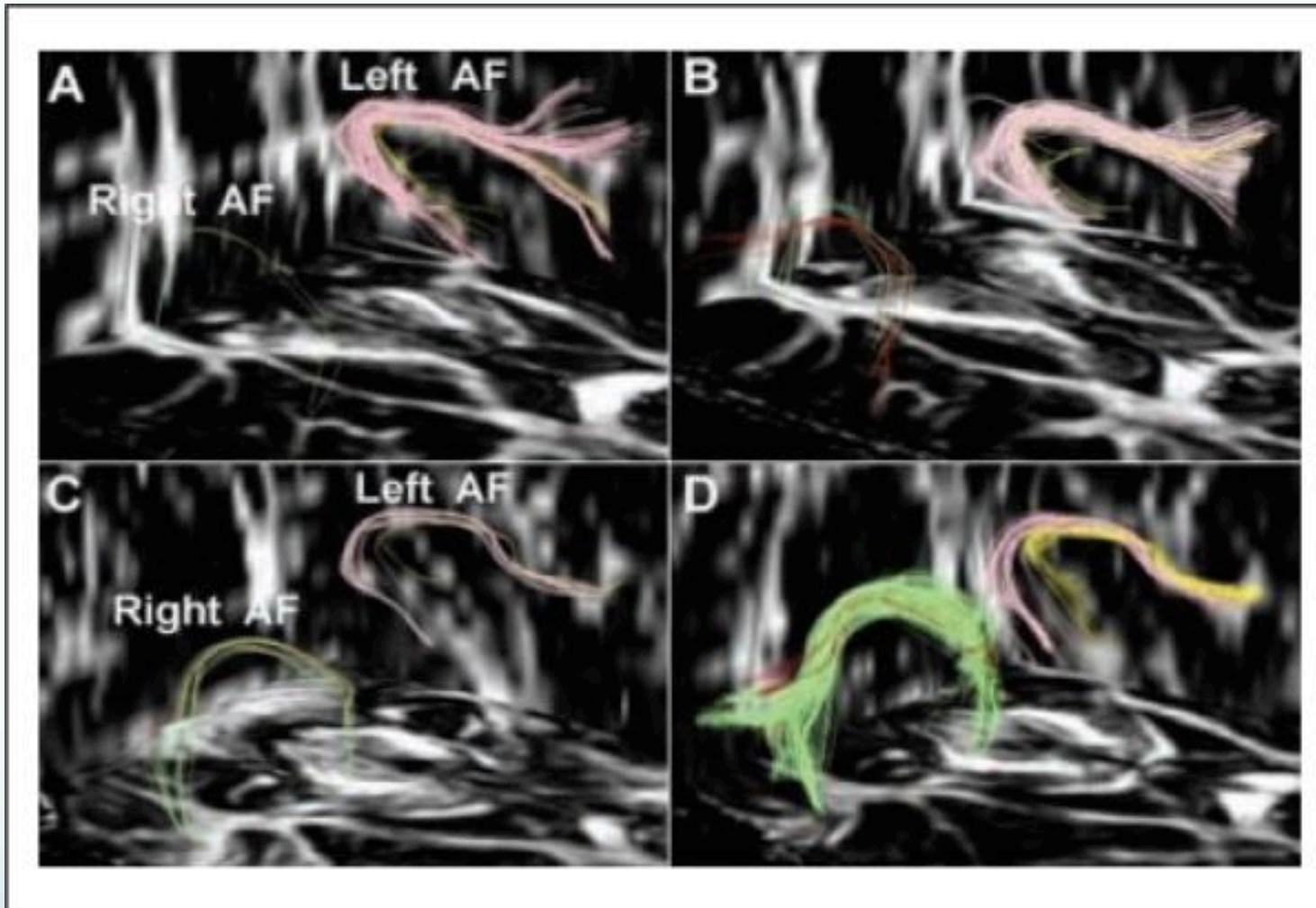
1. Group brain deformation differences. The brain images in panels A, B, and C show the location of the brain regions where instrumental children showed greater relative voxel size change over the 15 months compared to controls.

(A) Faisceau arqué d'un musicien instrumentiste de 65 ans



(B) Faisceau arqué d'un sujet non musicien de 63 ans, apparié par ailleurs sur la latéralité manuelle, le sexe et le QI global

Enfant de 8 ans sans aucune expérience musicale  
scanné à deux reprises (A et B) à 2 ans d'intervalle



Enfant de 8 ans avant (C) et après (D) deux ans  
d'apprentissage d'un instrument à cordes

Changements dans le faisceau arqué  
après apprentissage d'un instrument



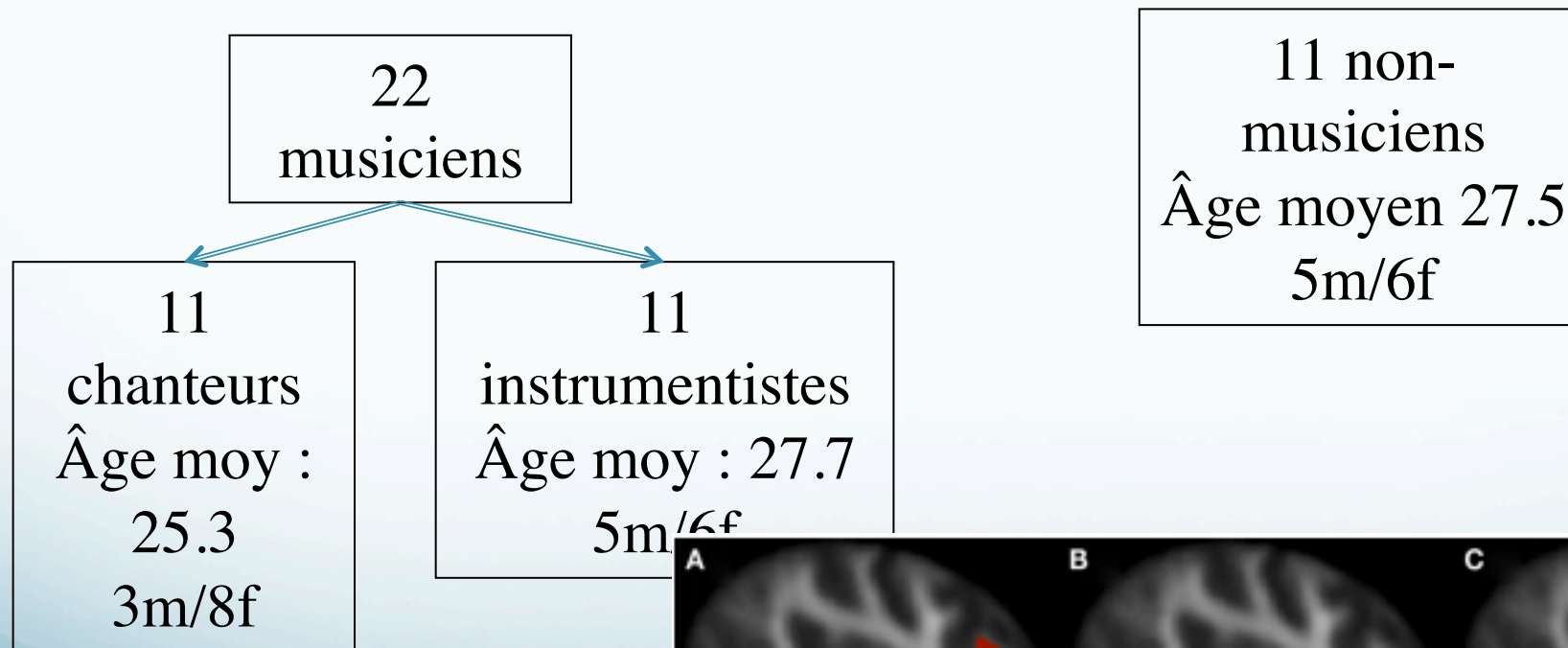
## Effects of practice and experience on the arcuate fasciculus: comparing singers, instrumentalists, and non-musicians

Gus F. Halwani<sup>1,2</sup>, Psyche Loui<sup>2</sup>, Theodor Rüber<sup>2,3</sup> and Gottfried Schlaug<sup>2\*</sup>

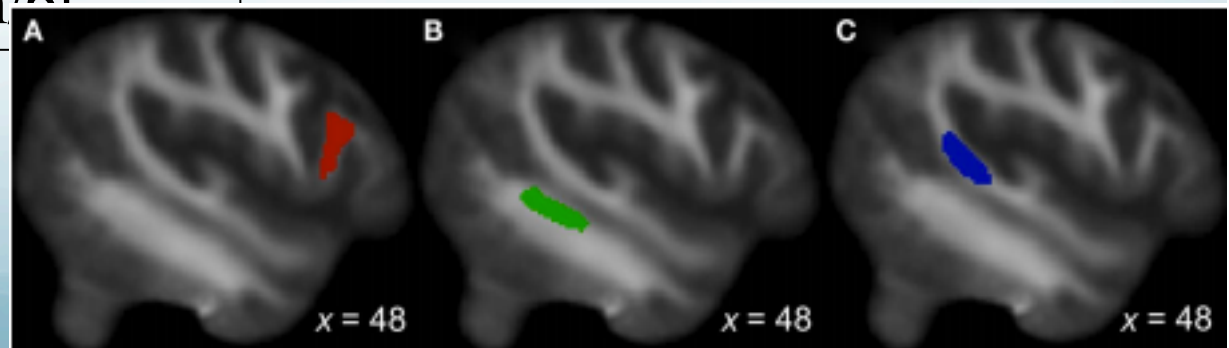
<sup>1</sup> Program in Speech and Hearing Bioscience and Technology, Harvard-MIT Division of Health Sciences and Technology, Massachusetts Institute of Technology, Cambridge, MA, USA

<sup>2</sup> Music and Neuroimaging Laboratory, Department of Neurology, Beth Israel Deaconess Medical Center/Harvard Medical School, Boston, MA, USA

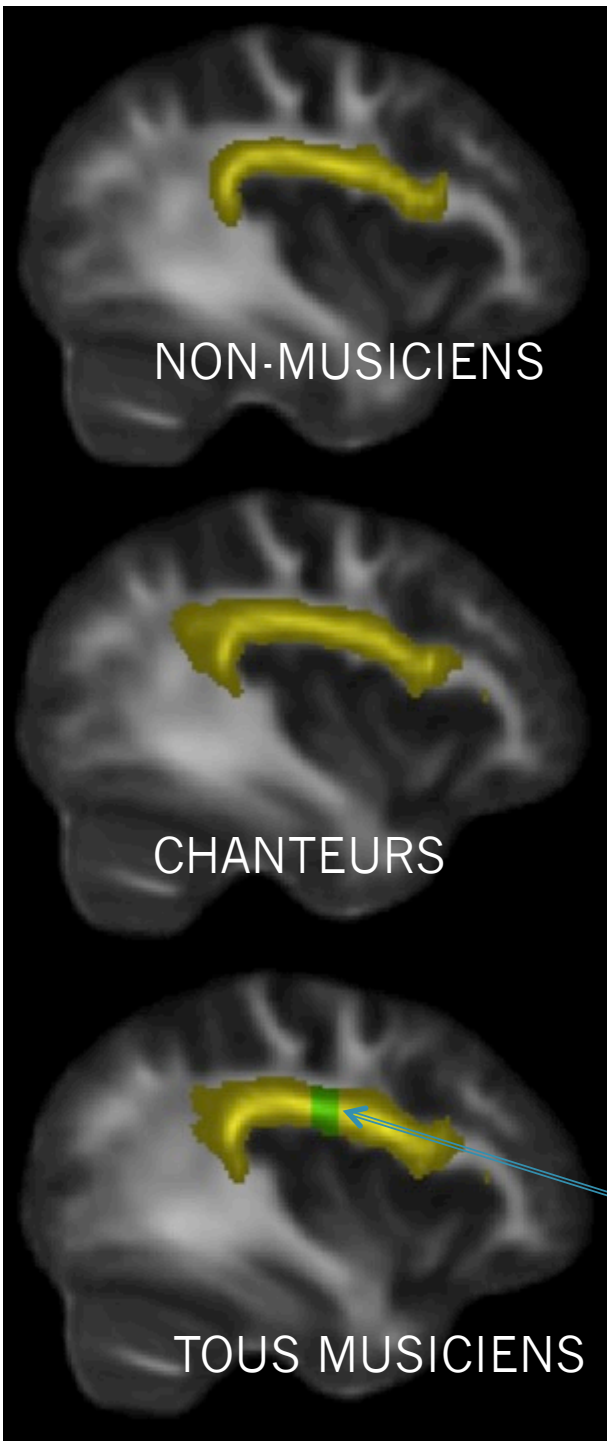
<sup>3</sup> Department of Epileptology, Bonn University Hospital, Bonn, Germany



Détermination faisceau  
arqué ROI



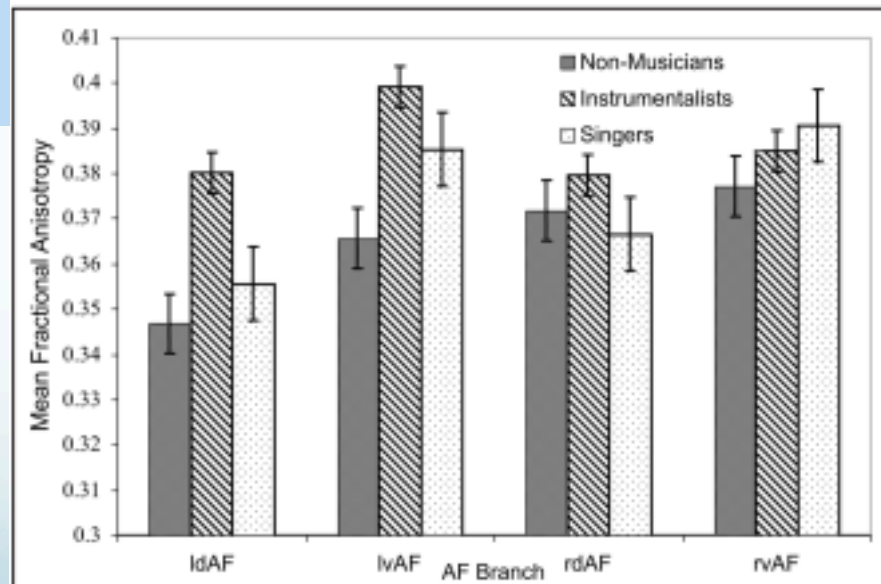
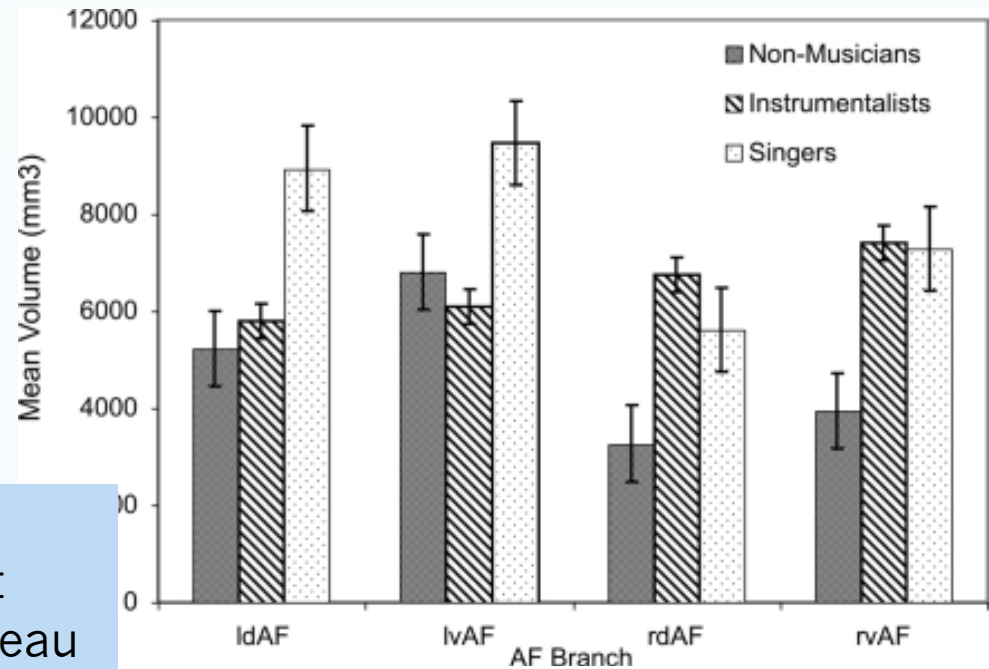




Différences  
prédominant  
dans le faisceau  
arqué gauche,  
partie dorsale

anisotropie

Zone de  
différence  
d'anisotropie

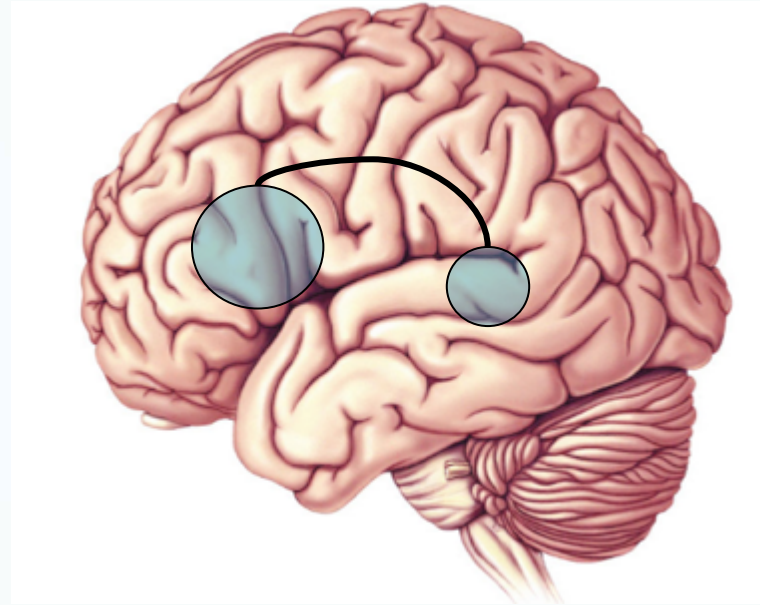


**FIGURE 3 | Mean FA for all branches of the AF in both hemispheres for all groups (l = left, r = right, d = dorsal, v = ventral). Error bars represent SE of the mean.**

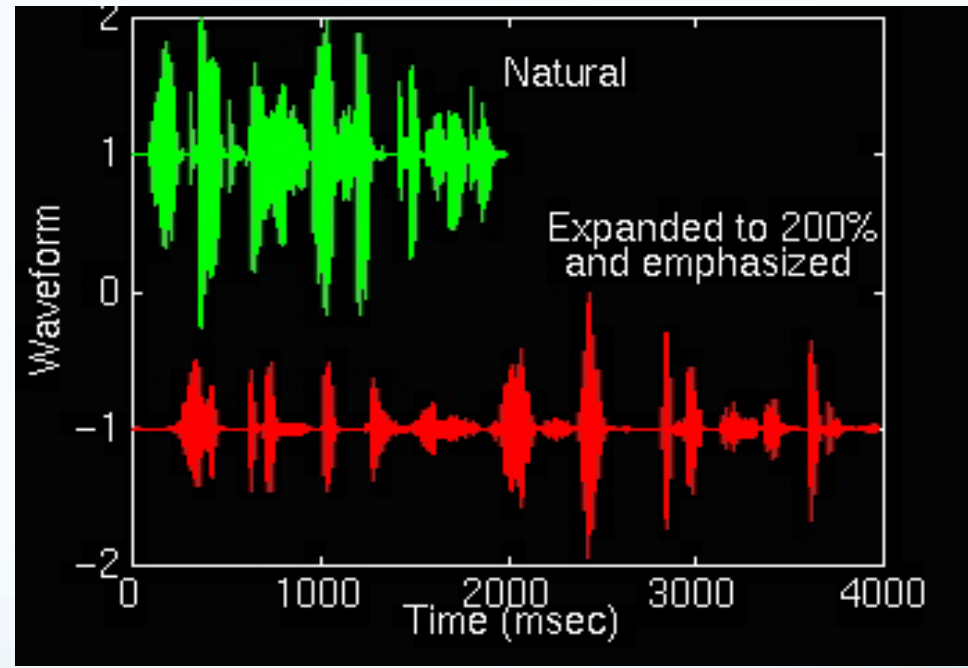
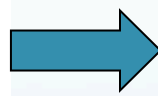


# Conclusion

- Les troubles « DYS » pourraient fort bien s'expliquer par un trouble de la connectivité inter-modalitaire (défaut dans les connexions à longue distance intra-cérébrales)
- La pratique d'un instrument de musique ou du chant est capable de modifier durablement la morphologie de ces connexions
- Un entraînement musical, et plus particulièrement l'apprentissage d'un instrument de musique, serait-il capable de modifier les connexions dysfonctionnelles chez les enfants souffrant de troubles DYS?



Plasticité rééducative :  
exemple de l'entraînement  
phonologique



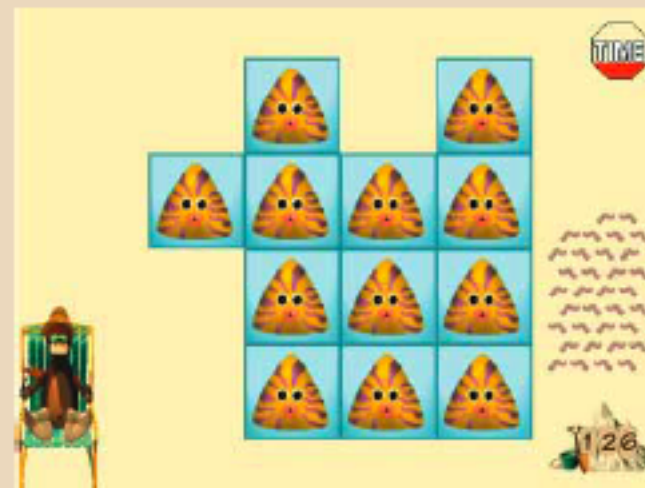


Box 1 | **The Fast ForWord® neuroplasticity-based training approach**

Circus Sequence



Phonic Match



Phonic Word



Language Comprehension Builder

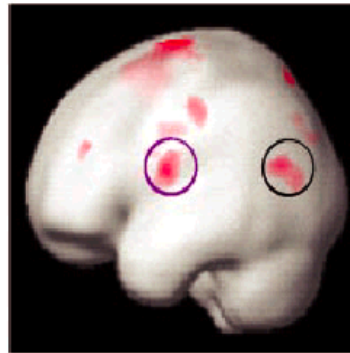


Fast ForWord®, developed by Scientific Learning Corporation, is a series of neuroplasticity-based training programmes that are designed to improve fundamental aspects of oral and written language comprehension and fluency. The exercises incorporate two simultaneous

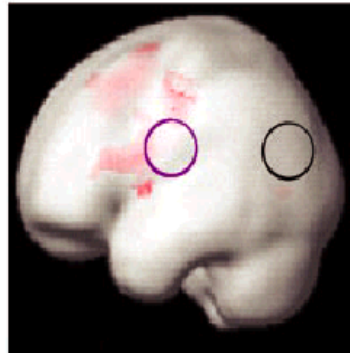


### A Children with no remediation

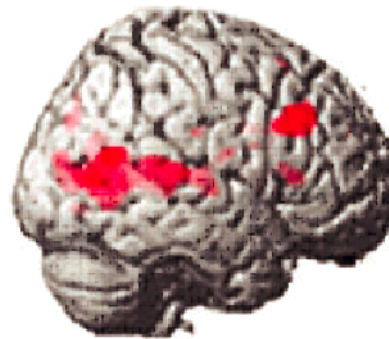
Normal reading children  
while rhyming



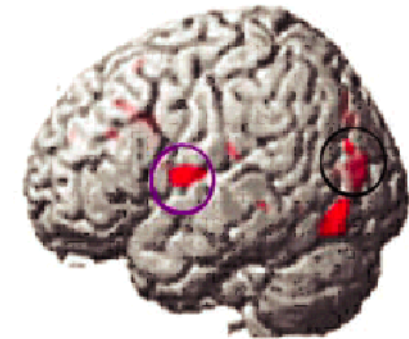
Dyslexic reading children  
while rhyming  
before remediation



### B Dyslexic children increases after remediation



Right



Left

# Entraînement temporo-phonologique : le programme "Lavande"

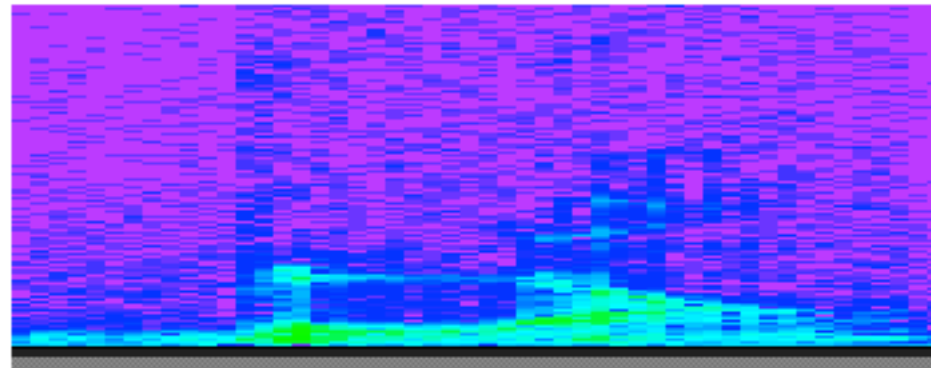
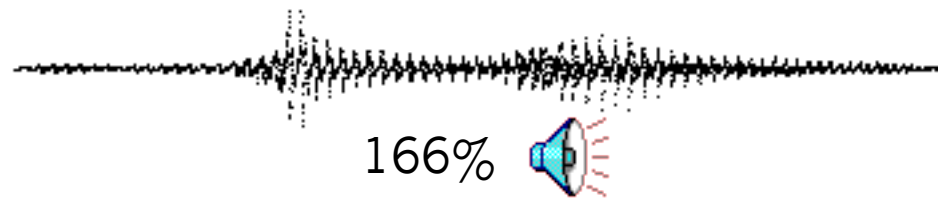
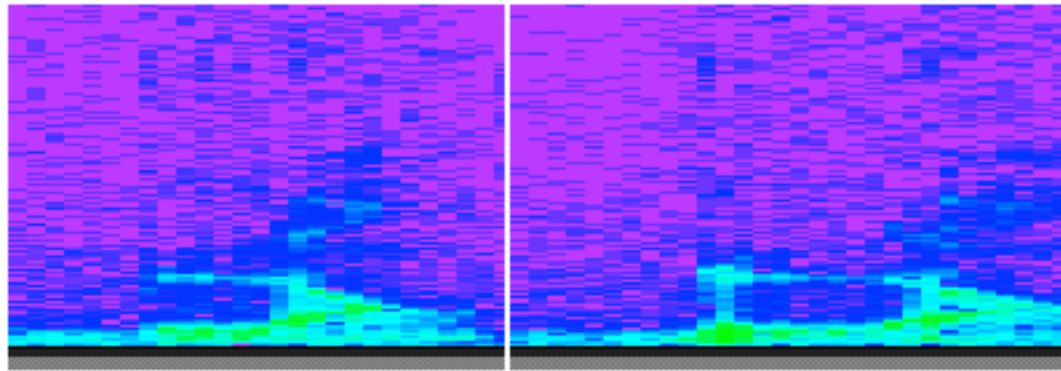
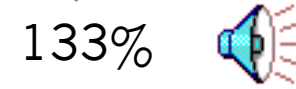
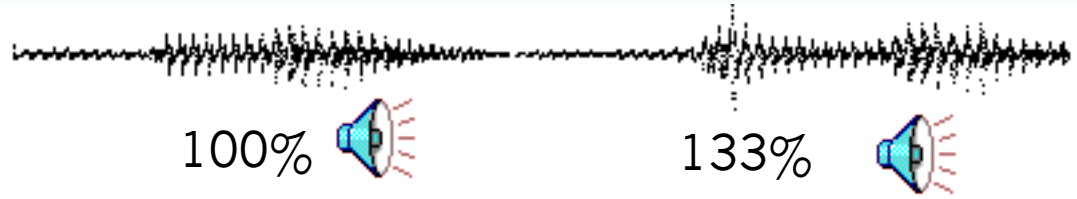
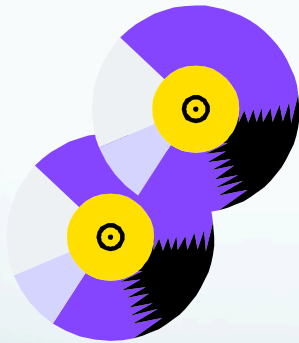
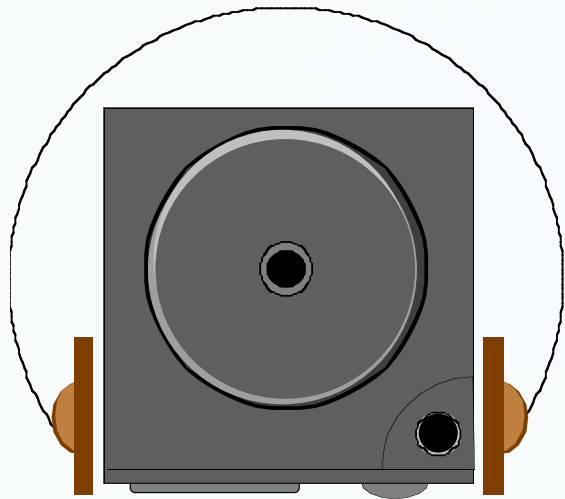
déficit temporel chez les  
'Language Learning Impaired'



trouble de la conscience  
phono. chez dyslexiques

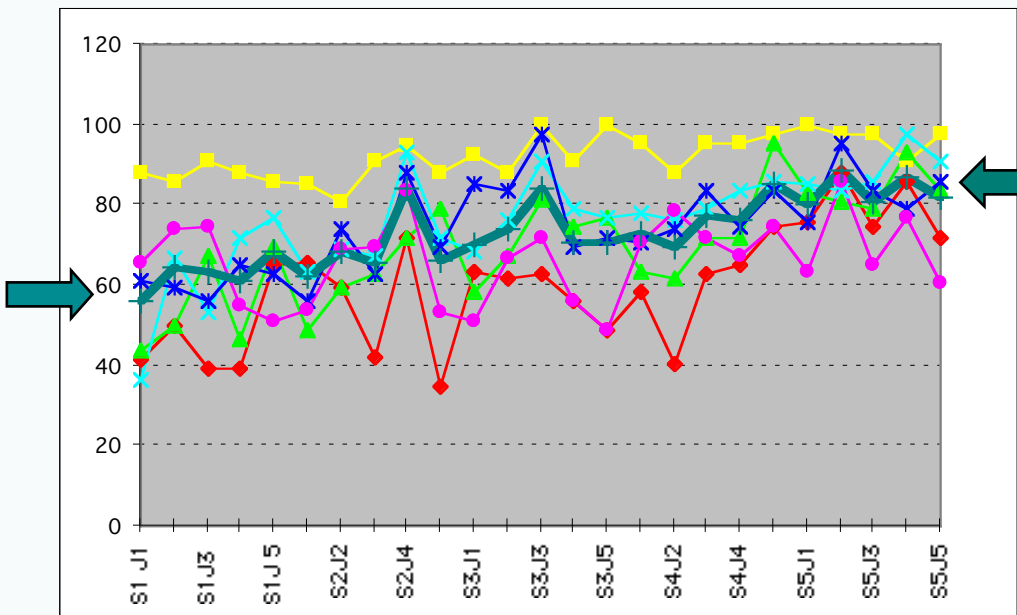


Combinaison d'un  
entraînement phonologique  
et temporel:  
Modification acoustique de la  
parole dans exercices de  
conscience phonologique

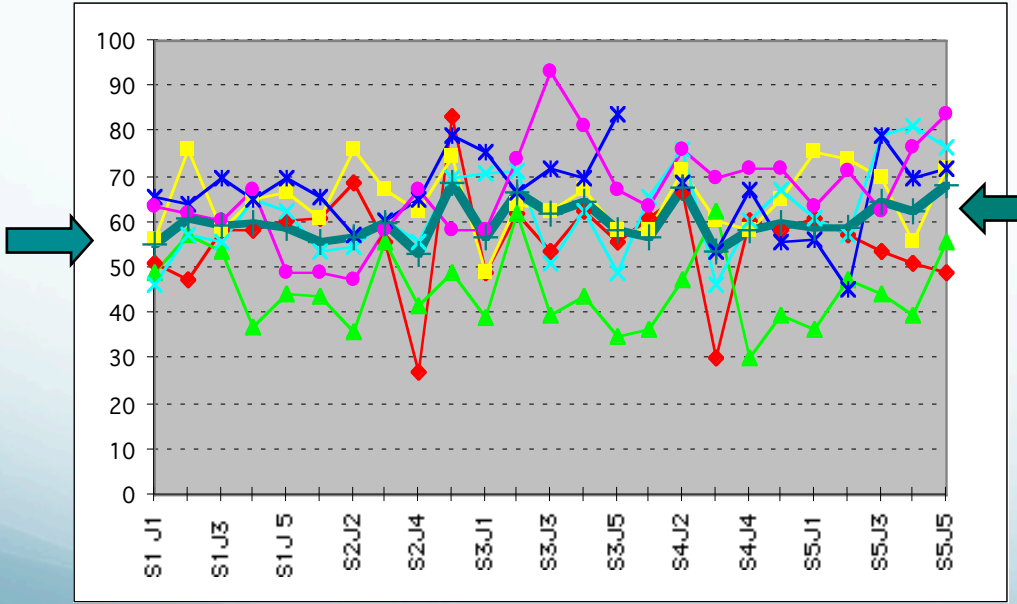


# Programme “Lavande” : Caractéristiques des exercices d’entraînement

	<b>structure syllabique simple</b>	<b>structure syllabique complexe</b>
trouver l'intrus qui ne commence pas pareil	<i>ex:</i> dauphin-tonneau-démon	<i>ex:</i> palto-plati-paltu
trouver l'intrus qui contient un son cible	<i>ex:</i> /d/ : pitou-bodu mité-nintan	<i>ex:</i> /sp/ : aspoɸit apsofal-aspoɸul
dictée de non-mots	<i>ex:</i> sujachi	<i>ex:</i> aclipsu



**Groupe expérimental**  
(6 enfants avec parole modifiée)



**Groupe placebo**  
(6 enfants avec parole normale)



# Plastic neural changes and reading improvement caused by audiovisual training in reading-impaired children

T. Kujala\*†, K. Karma‡, R. Ceponiene\*, S. Belitz\*, P. Turkkila‡, M. Tervaniemi\*, and R. Näätänen\*§

\*Cognitive Brain Research Unit, Department of Psychology, P.O. Box 13, University of Helsinki, FIN-00014 Helsinki, Finland; †Sibelius Academy, Department of Music Education, FIN-00251 Helsinki, Finland; and §BioMag Laboratory, Meilahti, P.O. Box 340, 00029 HUS, Finland

# Game patterns

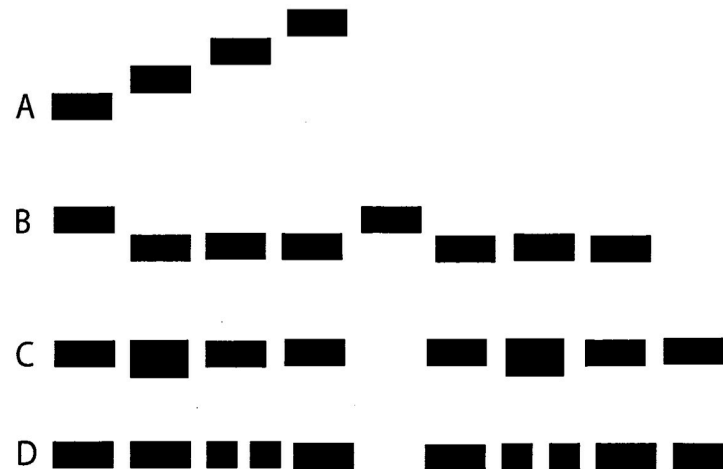
Version 1



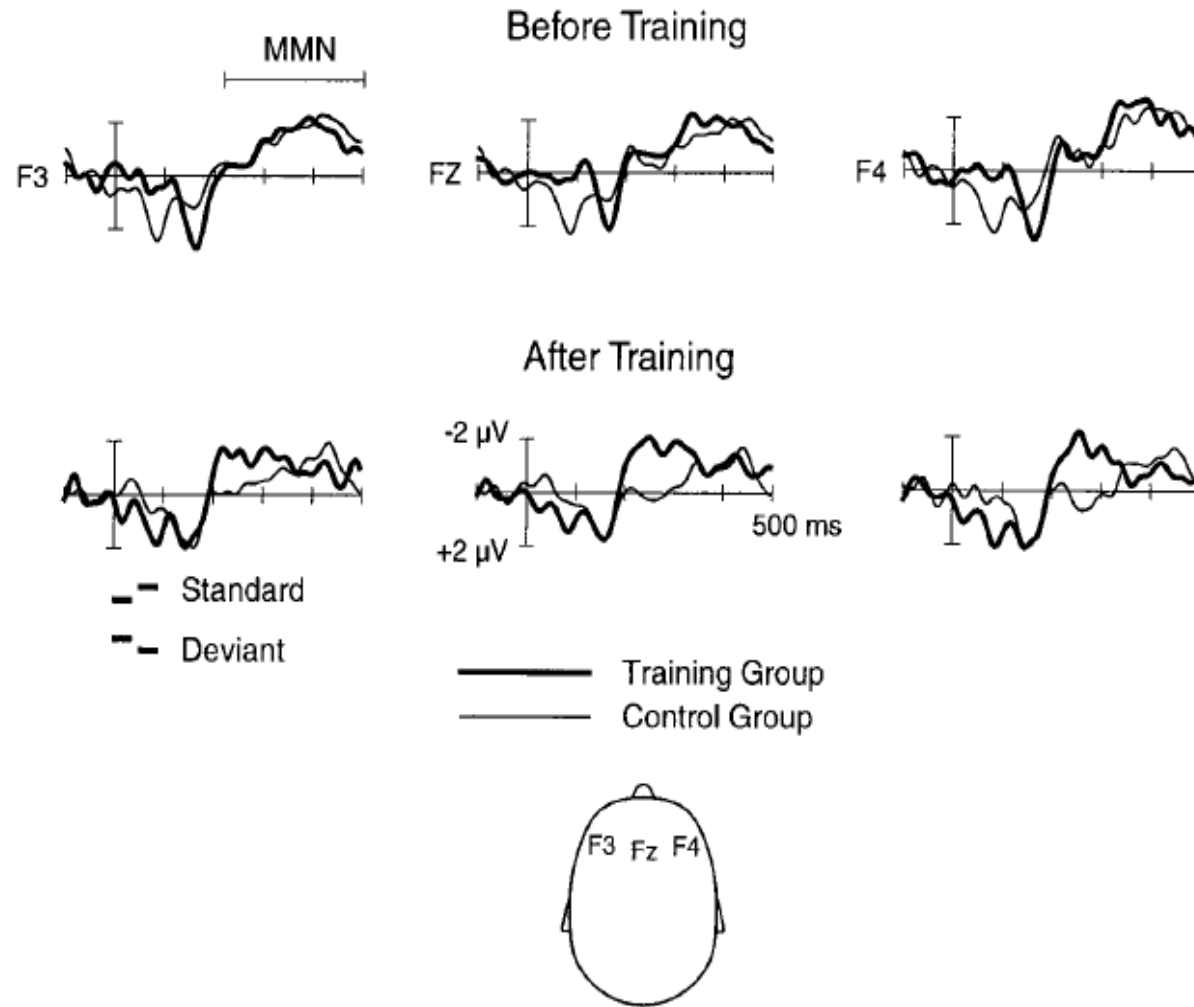
Version 2

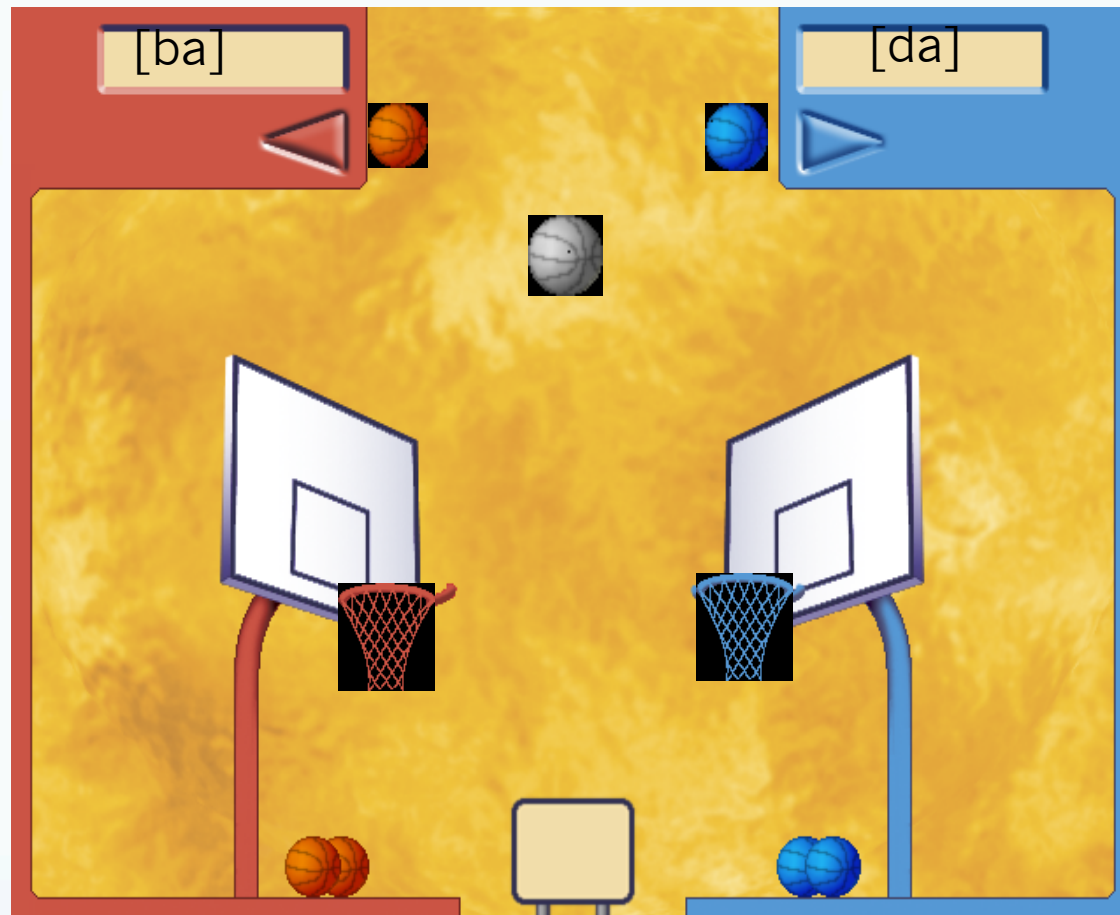


Pattern examples



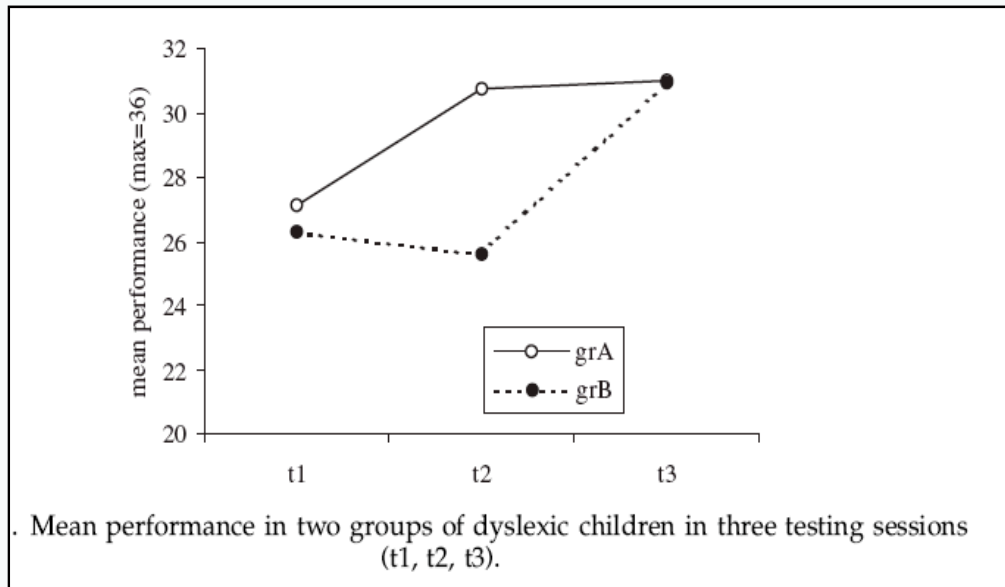
# Effects of Audio-Visual Training on MMN (Deviant-Standard)



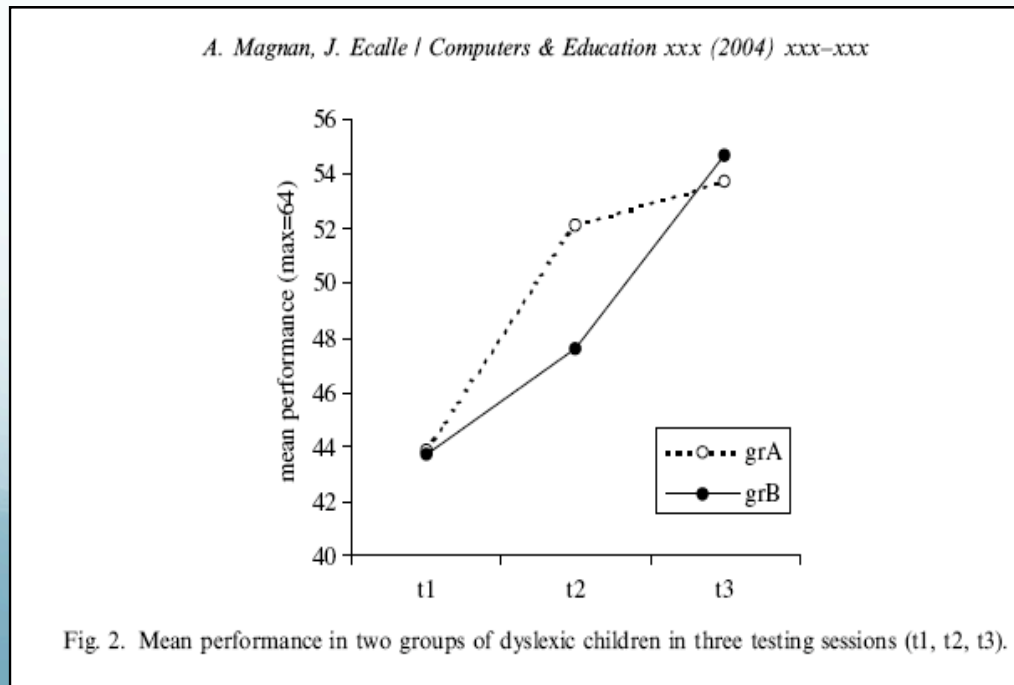


Intermodal training with « Play-on® » (Danon-Boileau & Barbier, 2000)

Danon-Boileau, L., & Barbier, D. (2000). Play-On: Un logiciel d'entraînement. Paris: Audivi-Media.



Performance moyenne en lecture (TIME2)



Performance moyenne en conscience phonologique





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

Andreas Widmann<sup>1\*</sup>, Erich Schröger<sup>1</sup>, Mari Tervaniemi<sup>2,3</sup>, Satu Pakarinen<sup>2</sup> and Teija Kujala<sup>2,4</sup>

<sup>1</sup> Institute of Psychology, University of Leipzig, Leipzig, Germany

<sup>2</sup> Cognitive Brain Research Unit, Cognitive Science, Institute of Behavioural Sciences, University of Helsinki, Helsinki, Finland

<sup>3</sup> Center of Excellence in Interdisciplinary Music Research, University of Jyväskylä, Jyväskylä, Finland

<sup>4</sup> Cicero Learning, University of Helsinki, Helsinki, Finland

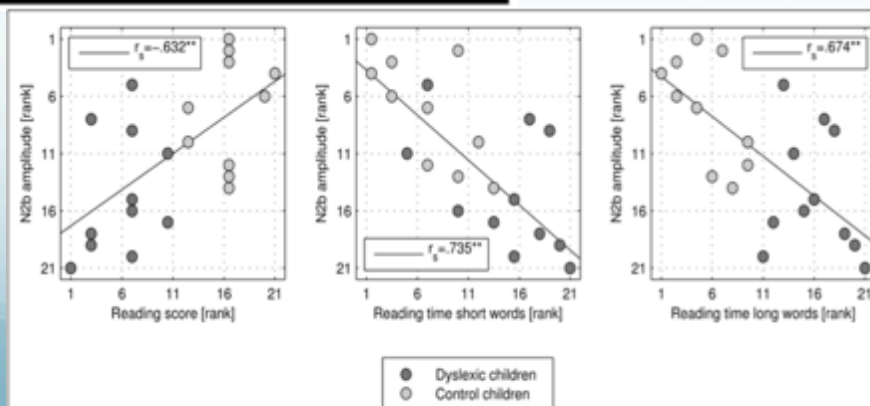
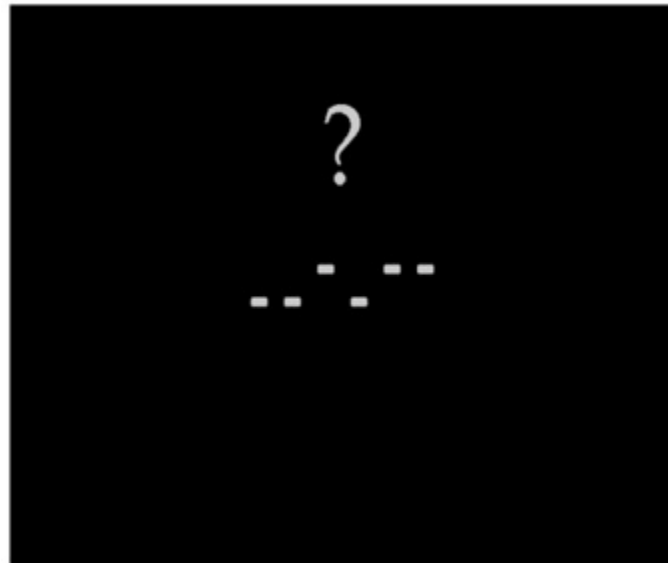
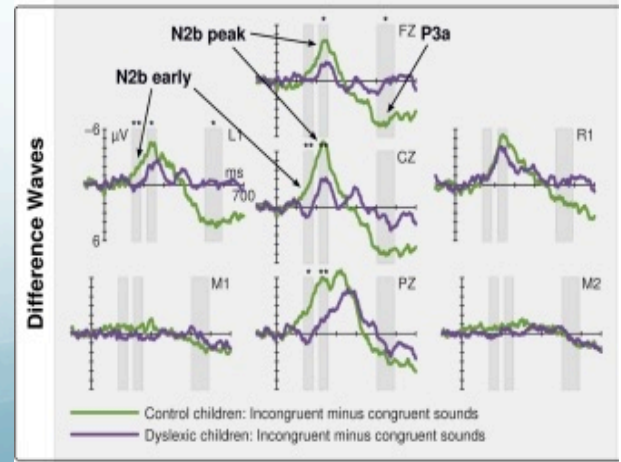
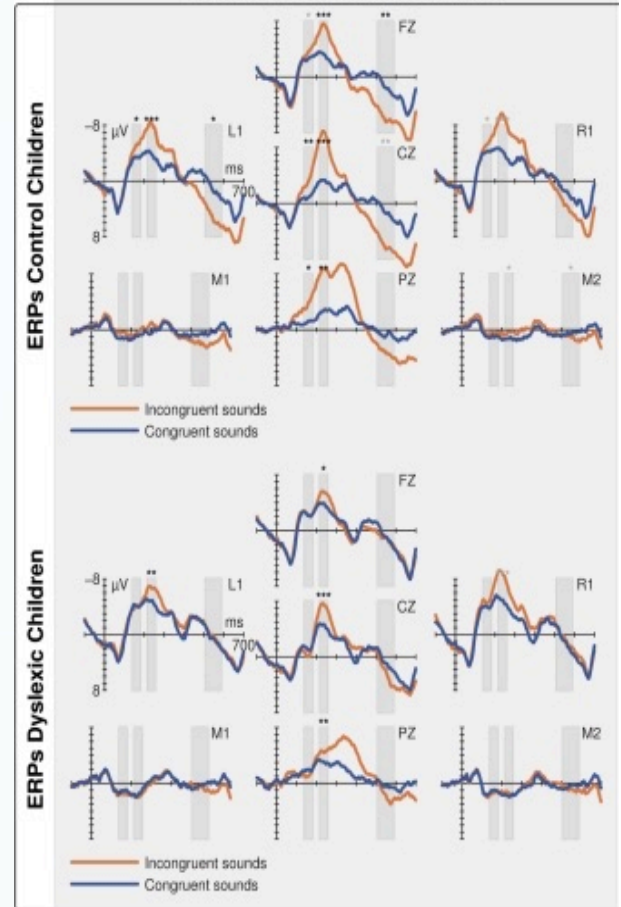
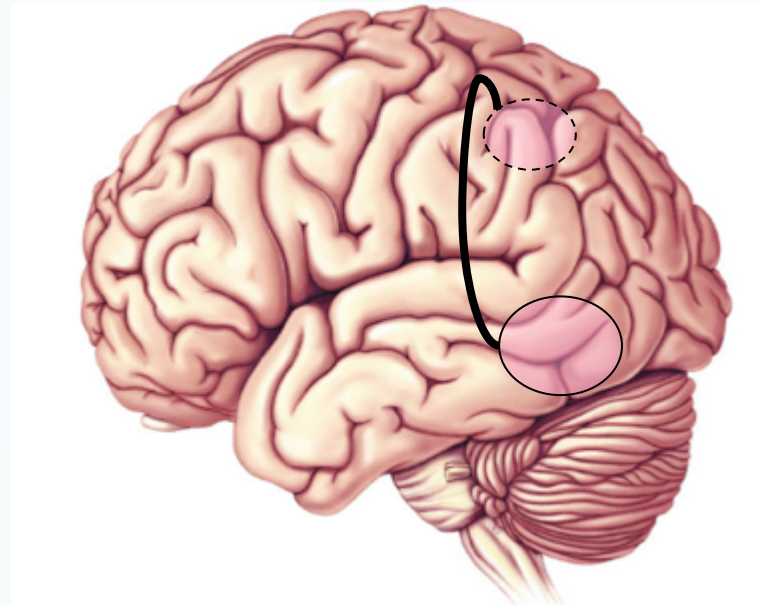


FIGURE 3 | Scatter plot and correlation of N2b amplitude rank (negative up) at electrode location Cz and rank of reading score, and reading time of short and long words, respectively.

## A Symbol-to-Sound-Matching Task



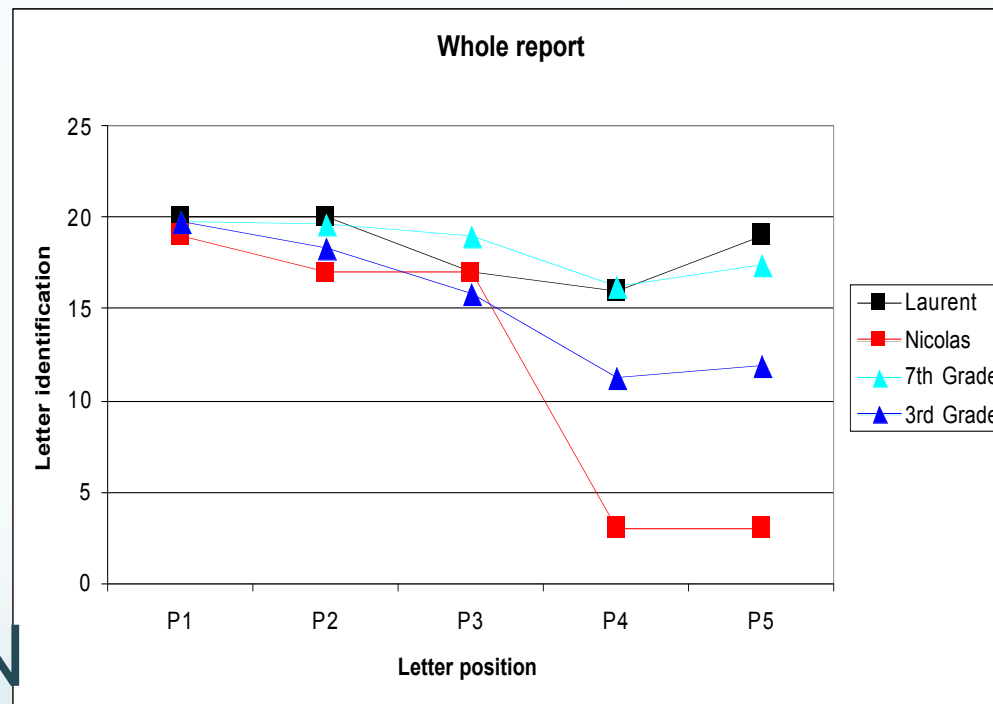


Plasticité rééducative: agir  
sur les systèmes de  
l'attention

# Notion d'empan visuo-spatial (S. Valdois)



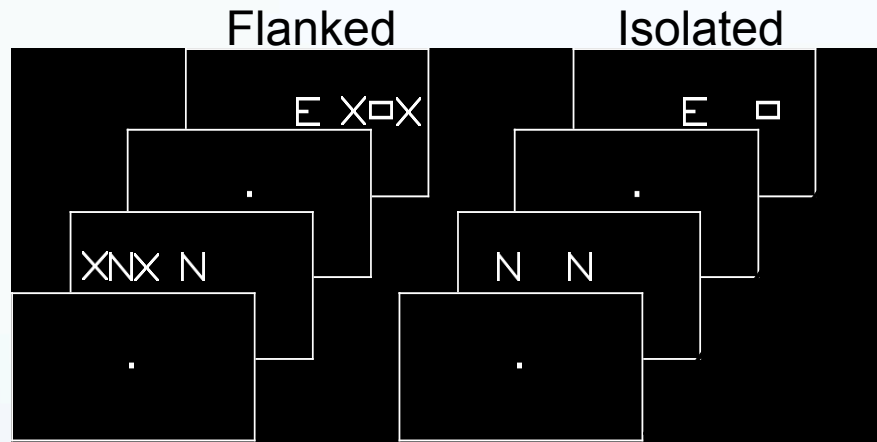
EMPAN



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

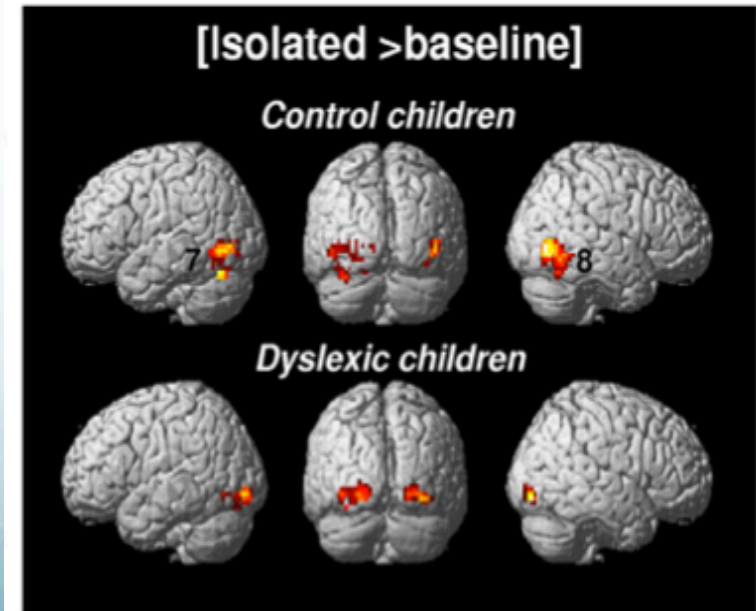
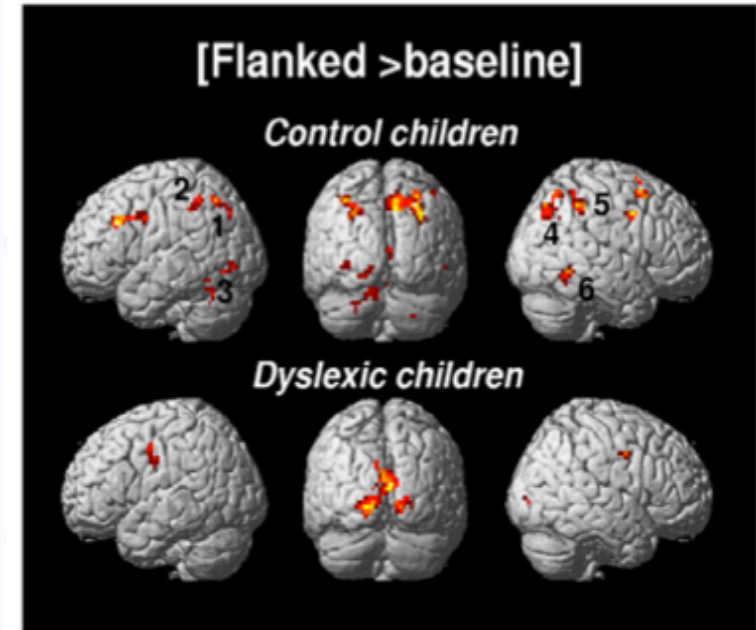
C. Peyrin<sup>a</sup>, J.F. Démonet<sup>b</sup>, M.A. N'Guyen-Morel<sup>c</sup>, J.F. Le Bas<sup>d</sup>, S. Valdois<sup>a,\*</sup>

## Tâche de catégorisation



- 12 dyslexic
- 12 CTL children

IRMf



# Exercices d'entraînement EVA

**450 exercices**

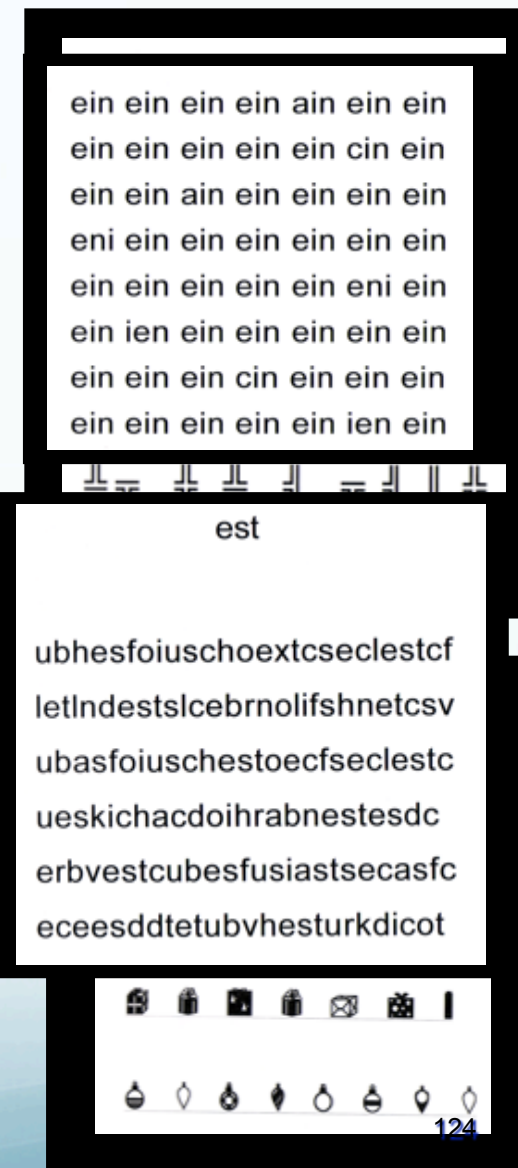
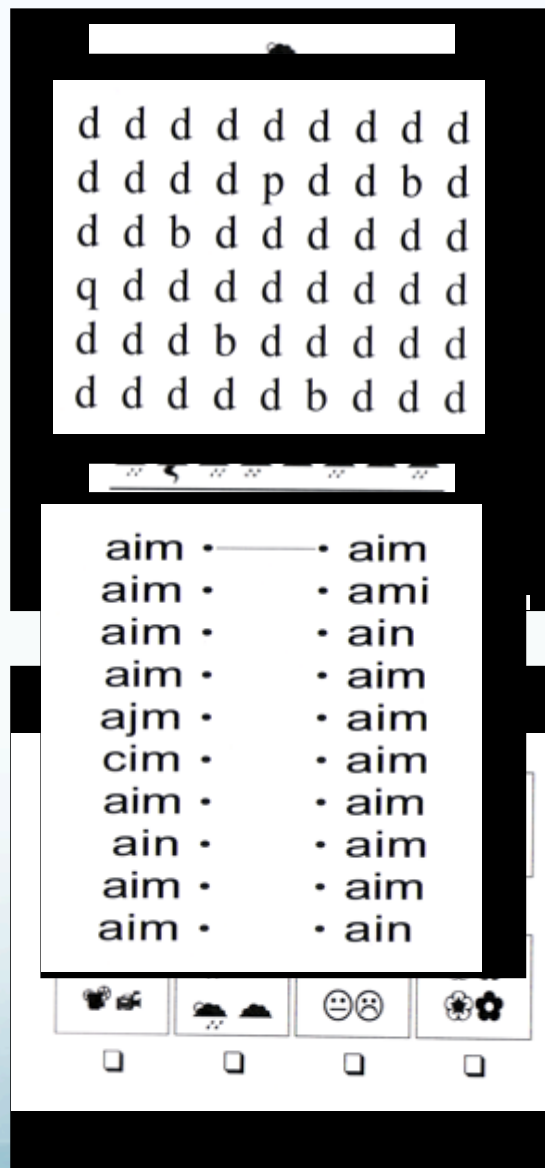
**intensif**

**Sur 6 semaines**

**Progression**

Non verbal → verbal

Un élément → 5 éléments



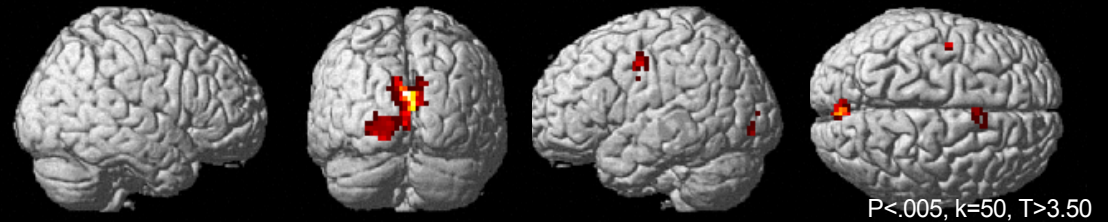


# Effet d'un entraînement VA

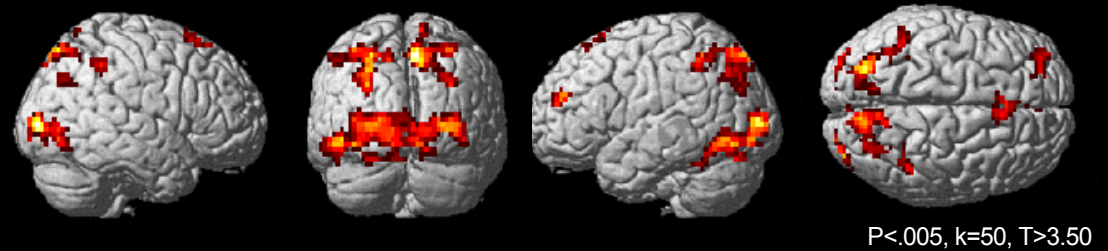
Réactivation des régions Pariétales après entraînement

## Enfants dyslexiques (n=12)

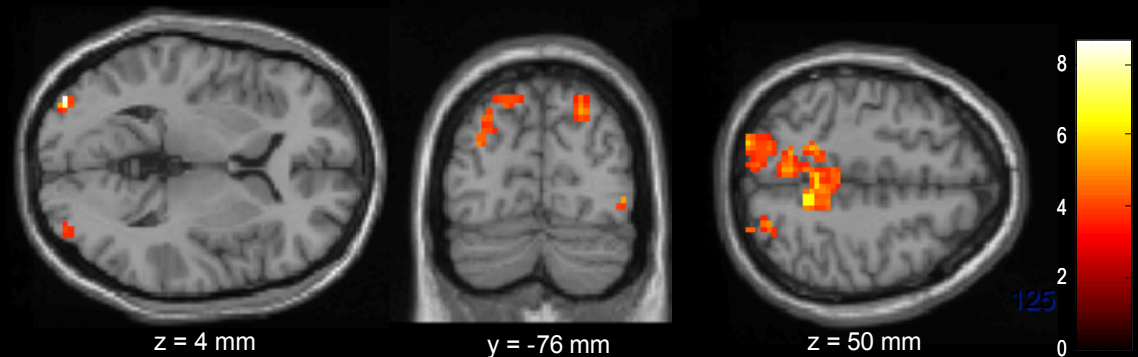
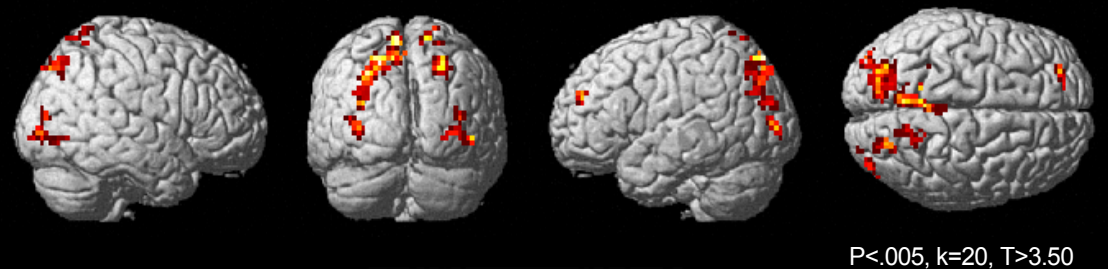
Avant entraînement VA [ENCHASSE > baseline]



Après entraînement VA [ENCHASSE > baseline]



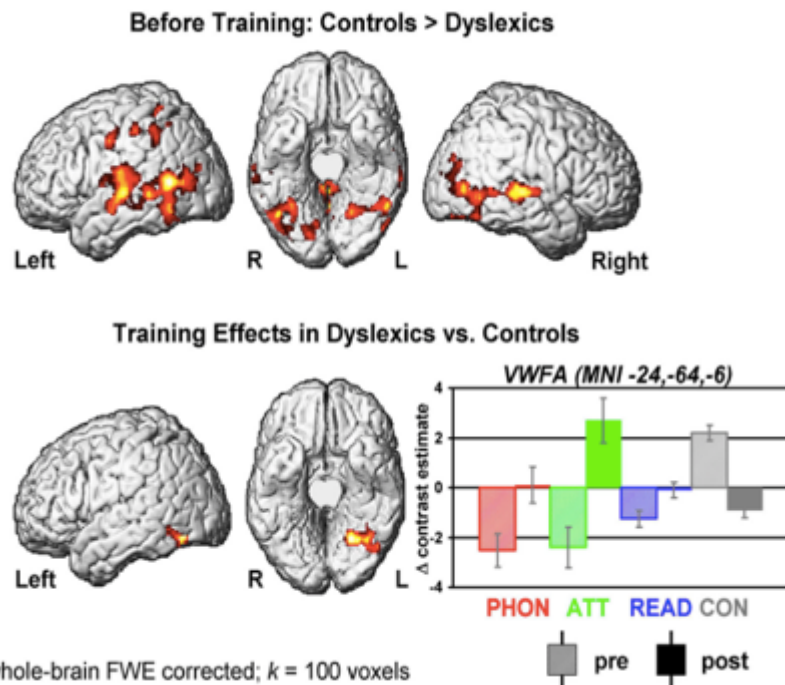
Effet de l'entraînement VA [ENCHASSE -Après > ENCHASSE -Avant]



## Shared vs. specific brain activation changes in dyslexia after training of phonology, attention, or reading

Stefan Heim · Julia Pape-Neumann ·  
Muna van Ermingen-Marbach · Moti Brinkhaus ·  
Marion Grande

Received: 30 August 2013 / Accepted: 17 April 2014



33 dyslexic readers receiving 20 training sessions each (typically 5 days per week for 4 weeks) of 30 min per session. The normal readers only underwent the same amount of diagnostic sessions as the dyslexic readers, but obtained no training.

The dyslexic readers were assigned to one of three different types of training: A phonology-based training ( $n = 12$ ), an attention-based training ( $n = 7$ ), or a pure reading training ( $n = 14$ ). All trainings were administered using laptop PCs to ensure comparability.

## Résultats

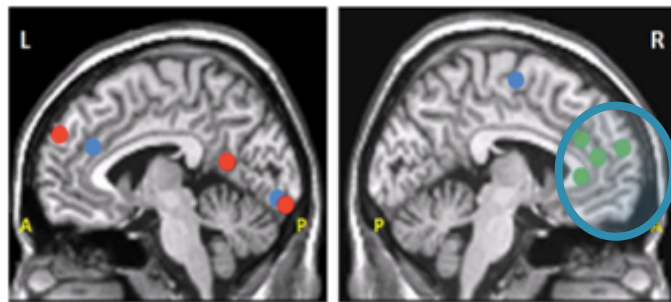
- comportementaux : les 3 méthodes améliorent de façon similaire la lecture, le groupe PHON améliore spécifiquement la phonologie, le groupe ATT l'attention

- imagerie (protocole de lecture silencieuse puis orale) : activation différentielle de la VWFA (fusiforme gauche) dys>cont. Pour les 3 groupes, sans différence significative entre les groupes.

## Reading acceleration training changes brain circuitry in children with reading difficulties

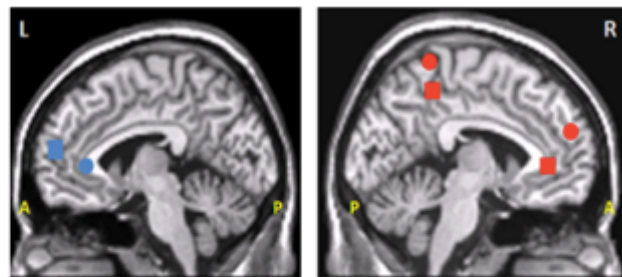
Tzipi Horowitz-Kraus, Jennifer J. Vannest, Darren Kadis, Nicole Cicchino, Yingying Y. Wang & Scott K. Holland

Pediatric Neuroimaging Research Consortium, Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio



- Main effect, Group
- Main effect, Training with RAP
- Group x Training with RAP interaction

Zone cingulaire antérieure : plus fort différentiel d'activation chez les dyslexiques que les normo-lecteurs



- Children with RD, reading rate
- Children with RD, reading accuracy
- Typical readers, reading rate
- Typical readers, reading accuracy

Corrélation entre l'amélioration de la précision et la rapidité de lecture et les régions d'intérêt. Chez les DYS, corrélé à la région frontale médiane et cingulaire



# Cortical Signatures of Dyslexia and Remediation: An Intrinsic Functional Connectivity Approach

Maki S. Koyama<sup>1,2\*</sup>, Adriana Di Martino<sup>2</sup>, Clare Kelly<sup>2</sup>, Devika R. Jutagir<sup>2</sup>, Jessica Sunshine<sup>2</sup>, Susan J. Schwartz<sup>3</sup>, Francisco X. Castellanos<sup>2,4</sup>, Michael P. Milham<sup>3,4</sup>

<sup>1</sup>Rutgers University Center for Molecular and Behavioral Neuroscience, Newark, New Jersey, United States of America, <sup>2</sup>Phyllis Green and Randolph Cowen Institute for Pediatric Neuroscience, New York University Child Study Center, NYU Langone Medical Center, New York, New York, United States of America, <sup>3</sup>Center for the Developing Brain, Child Mind Institute, New York, New York, United States of America, <sup>4</sup>Nathan Kline Institute for Psychiatric Research, Orangeburg, New York, United States of America

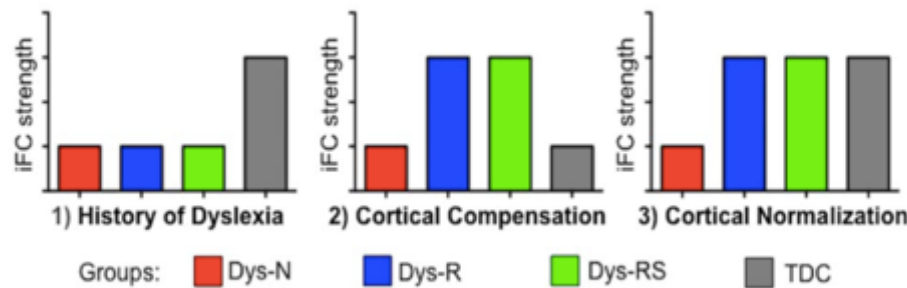


Figure 1. Hypothetical profiles of intrinsic functional connectivity. iFC = intrinsic Functional Co

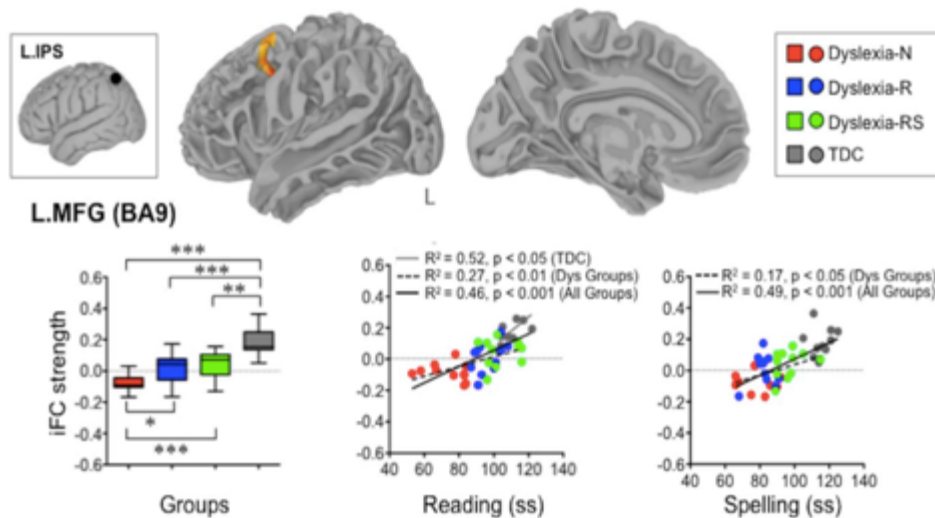


Figure 4. Atypical IFC between the left intraparietal sulcus (LIPS) and left middle frontal gyrus (L.MFG) associated with historical diagnosis of dyslexia. The box-and-whisker plot depicts LIPS-LMFG IFC for each group and group differences, whereas the two scatterplots

Etude de la connectivité intrinsèque dans 4 groupes d'enfants (âge moy 12a) :

- Dyslexiques non rééduqués
- Dyslexiques partiellement rééduqués (lect seul)
- Dyslexiques totalement rééduqués (lect + orthogr)
- Témoins à développement typique

*Effet lié à la dyslexie* : connectivité entre lobule pariétal Gche et gyrus frontal moyen Gche

*Effet lié à la compensation* : connectivité entre VWFA et CPM (systèmes de **l'attention sélective**)

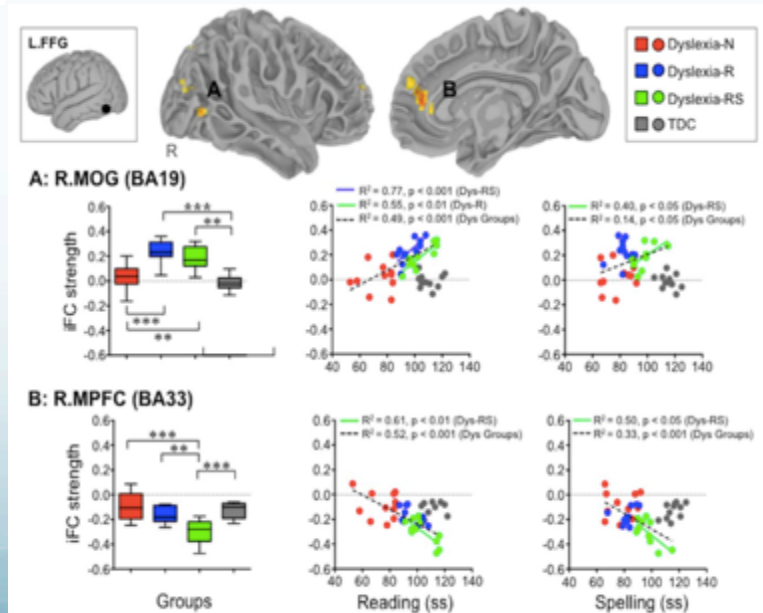


Figure 5. Compensatory changes in IFC of the left fusiform gyrus (LFFG) in the remediation groups. The box-and-whisker plots depict

## Binocular saccade coordination in reading and visual search: a developmental study in typical reader and dyslexic children

Magali Seassau<sup>1\*</sup>, Christophe Loic Gérard<sup>2</sup>, Emmanuel Bui-Quoc<sup>3</sup> and Maria Pia Bucci<sup>4</sup>

<sup>1</sup> eye)BRAIN, Ivry-sur-Seine, France

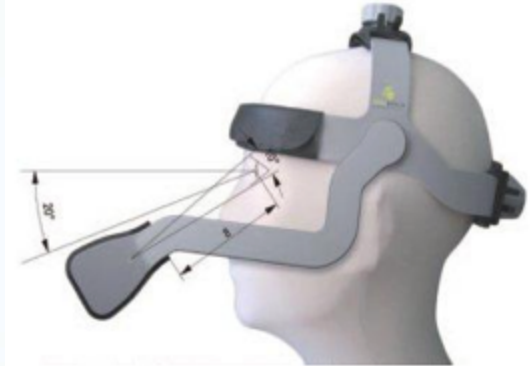
<sup>2</sup> Service de Psychopathologie de l'Enfant et de l'Adolescent, Hôpital Robert Debré, Paris, France

<sup>3</sup> Service d'Ophthalmologie, Hôpital Robert Debré, Paris, France

<sup>4</sup> UMR 1141 Inserm-Paris 7-Hôpital Robert Debré, Paris, France

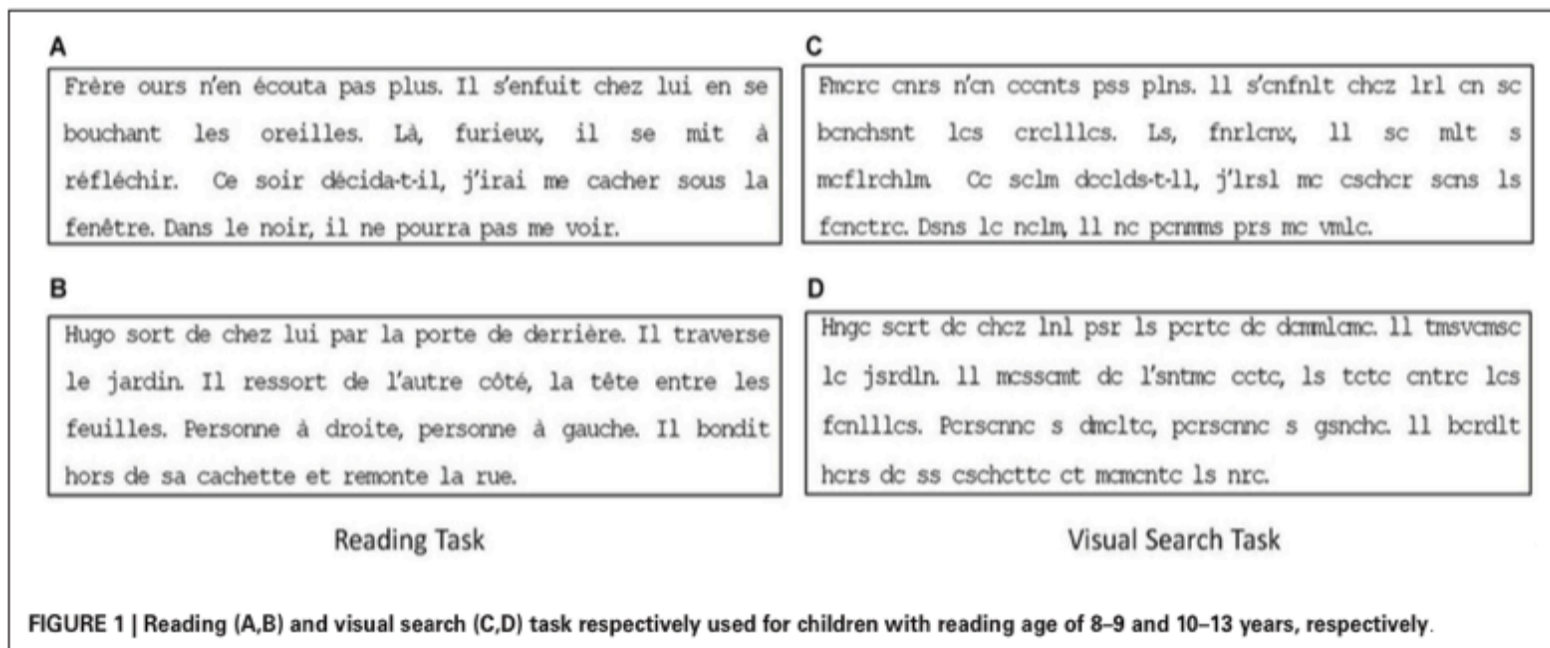
43 dyslexiques / 42 témoins  
âge 7-13

Eye-tracking device

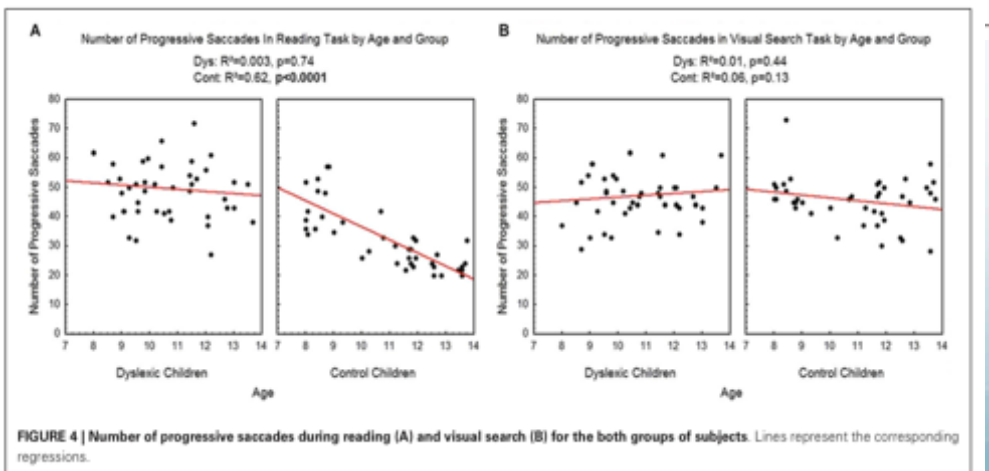
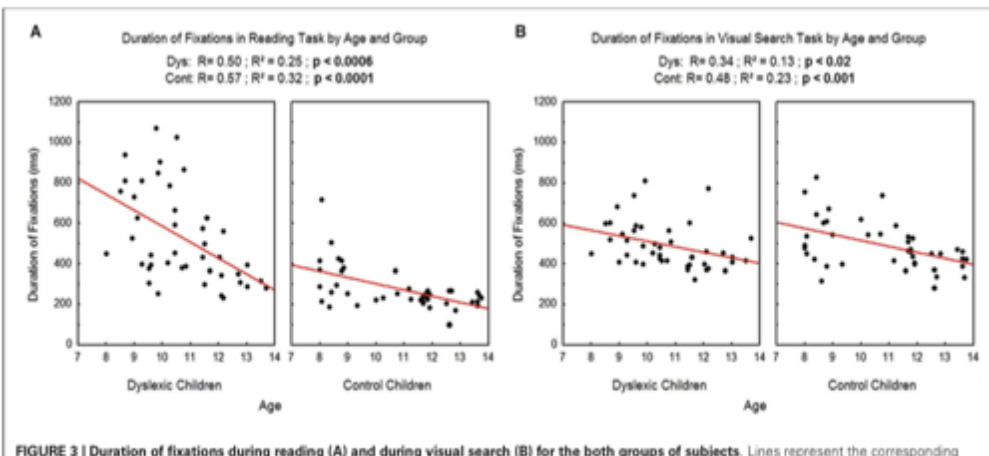
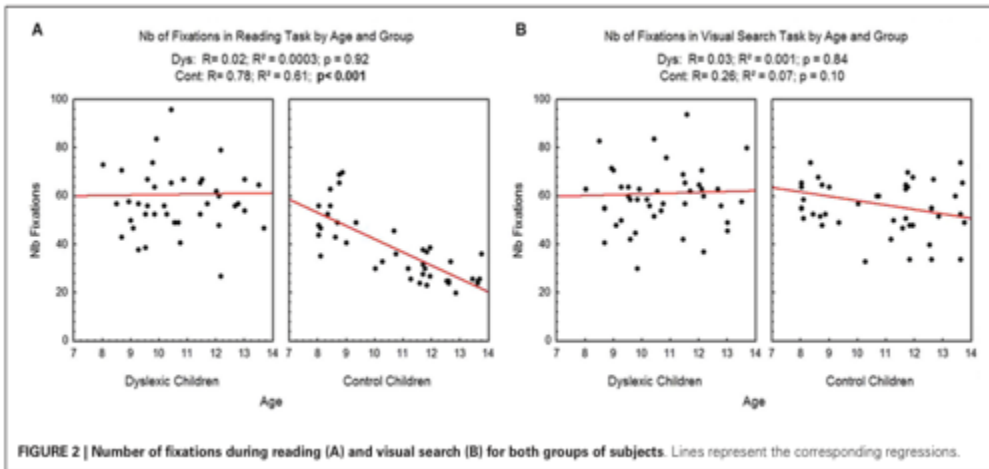


Lecture silencieuse

Compter les lettres 'r'







- Les témoins, au fur et à mesure qu'ils apprennent à lire, font moins de saccades et des fixations plus courtes et moins nombreuses
- Dyslexiques diffèrent des témoins pour la tâche de lecture, pas pour la tâche de recherche visuelle
- Effet développemental pour la tâche de lecture chez les témoins, pas chez les dyslexiques

*'The atypical eye movement's patterns observed in dyslexic children suggest a deficiency in the visual attentional processing as well as an impairment of the ocular motor saccade and vergence systems interaction'*

OPINION

# Sensory theories of developmental dyslexia: three challenges for research

Usha Goswami

Abstract | Recent years have seen the publication of a range of new theories suggesting that the basis of dyslexia might be sensory dysfunction. In this Opinion article, the evidence for and against several prominent sensory theories of dyslexia is closely scrutinized. Contrary to the causal claims being made, my analysis suggests that many proposed sensory deficits might result from the effects of reduced reading experience on the dyslexic brain. I therefore suggest that longitudinal studies of sensory processing, beginning in infancy, are required to successfully identify the neural basis of developmental dyslexia. Such studies could have a powerful impact on remediation.

**Ziegler, J. C. et al.** Rapid processing of letters, digits and symbols: what purely visual-attentional deficit in developmental dyslexia? *Dev. Sci.* **13**, F8–F14 (2010).

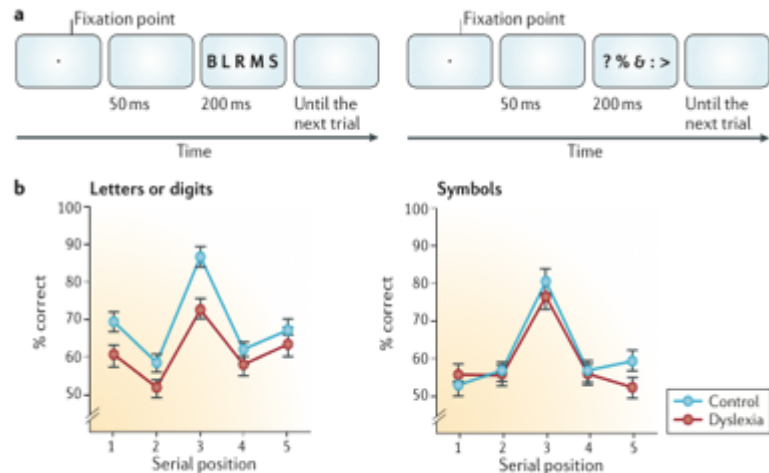
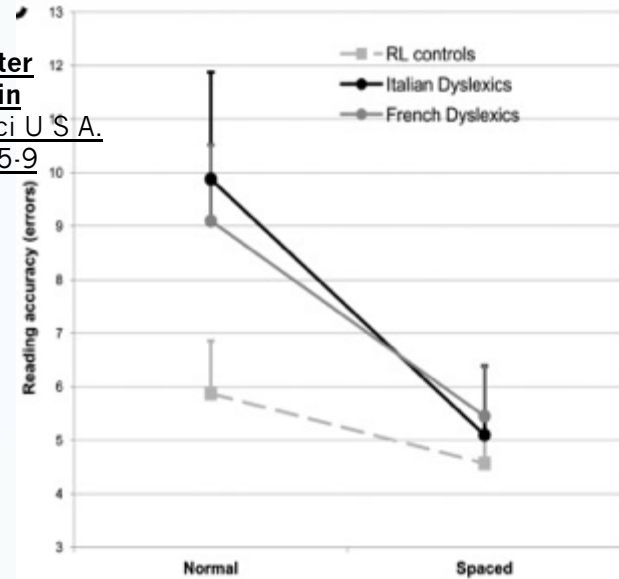


Figure 2 | Performance in the visual span task in dyslexia. a | The visual span task usually tests visual short-term memory by requiring an array of five letters or digits (left graph), but tests...

**Zorzi et al.** Extra-large letter spacing improves reading in dyslexia. *Proc Natl Acad Sci U S A.* 2012 Jul 10;109(28):11455-9

Non significatif si reading-level-matched



**Olulade, A. O., Napoliello, E. M. and Eden, G. F.** Abnormal visual motion processing is not a cause of dyslexia, *Neuron*, 79, 180–190, © Elsevier (2013).

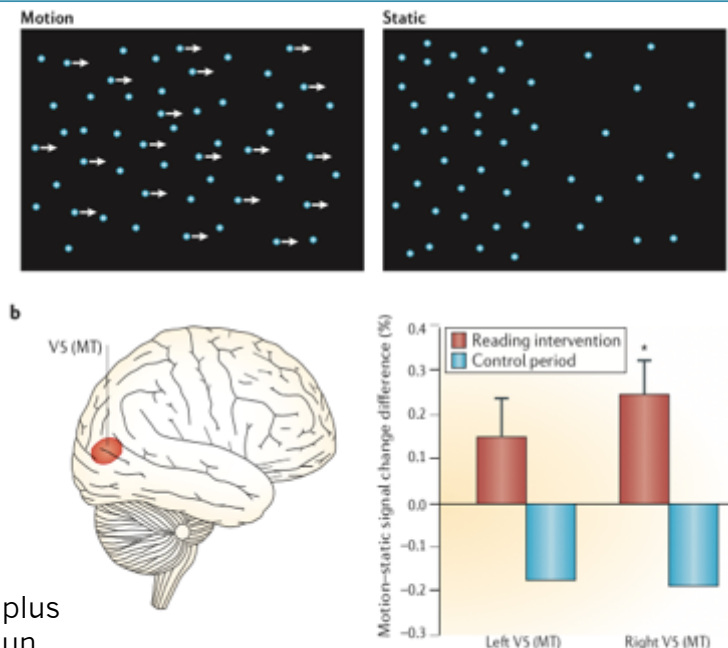


Figure 1 | Coherent motion detection and visual area 5 activation in dyslexia. Because motion...

Pas d'effet pour traitement de symboles non alphabétiques → l'effet s'explique par un codage lettre-son

Motion-mediated activation : plus forte après un traitement phonologique

## CORRESPONDENCE

### Visual attention deficits in developmental dyslexia cannot be ascribed solely to poor reading experience

Muriel Lobier and Sylviane Valdois

1°) Si un défaut d'empan VA était la conséquence d'une lecture déficiente, alors tous les enfants dyslexiques devraient avoir un déficit VA ce qui n'est pas le cas

2°) les résultats d'une étude de cas récente apportent une preuve supplémentaire en faveur de la causalité : dans cette étude, un entraînement de l'empan VA a débouché non seulement sur une amélioration de la lecture, mais aussi une réactivation des aires corticales associées à l'attention spatiale

3°) un défaut de mapping visuo-phonologique aurait prédit une faible performance à la tâche des points de couleur (recodage phonologique requis) ce qui n'a pas été le cas

4°) could result from poor near-floor performance of children both with and without dyslexia. Results that were obtained using an easier categorization task strongly indicate a similar deficit for unfamiliar, non-verbal characters in VA span-impaired children with dyslexia

## CORRESPONDENCE

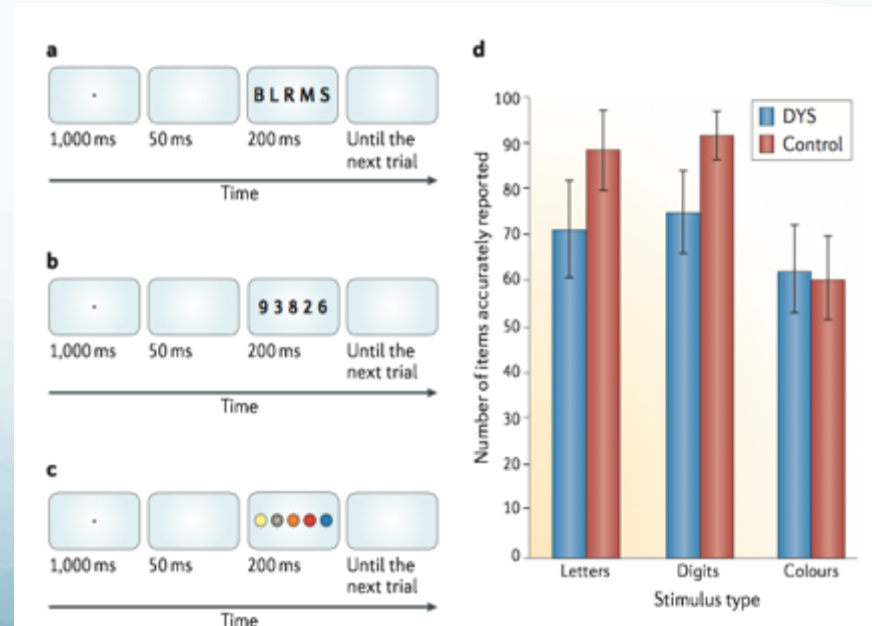
### Visual attention span deficits and assessing causality in developmental dyslexia

Usha Goswami

NATURE REVIEWS | NEUROSCIENCE

Published online 20 March 2015

« Unfortunately, all of the studies that were discussed used letters to assess VA span; thus, the demonstrated deficit only affects letters and is causally ambiguous »





## Cogmed Programs

Cogmed Working Memory Training is built around three easy-to-use and age-specific program applications.

### Cogmed **JM**

Pre-school

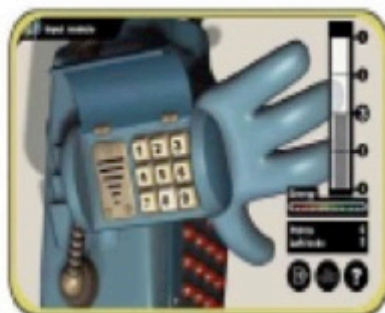
Younger children use their working memory for a number of things, such as focusing on and following instructions, and remaining seated to complete independent activities.



### Cogmed **RM**

School age

Working memory is crucial for children and adolescents in school and socially. Reading, solving math problems, planning, and following a conversation all rely on working memory.



### Cogmed **QM**

Adult

Working memory in adult and professional life is critical for challenges such as planning, focusing, resisting distraction, and meeting deadlines.



To learn more about our programs and about working memory, visit [www.cogmed.com](http://www.cogmed.com).

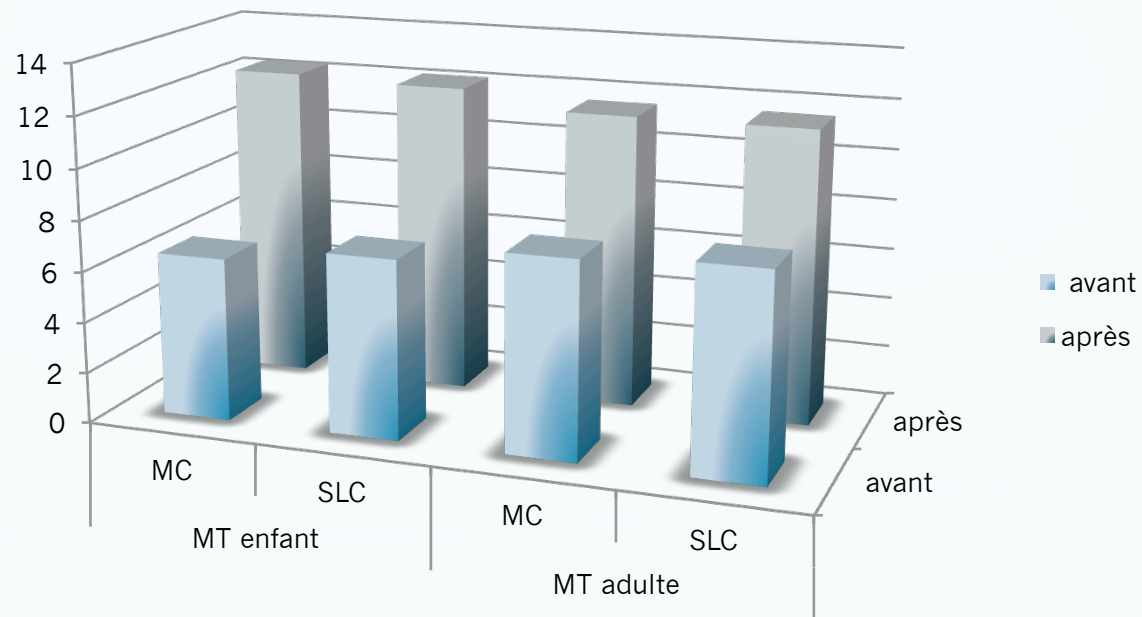


**COGMED**

Programme de  
remédiation de la  
mémoire de travail

### Training Curve

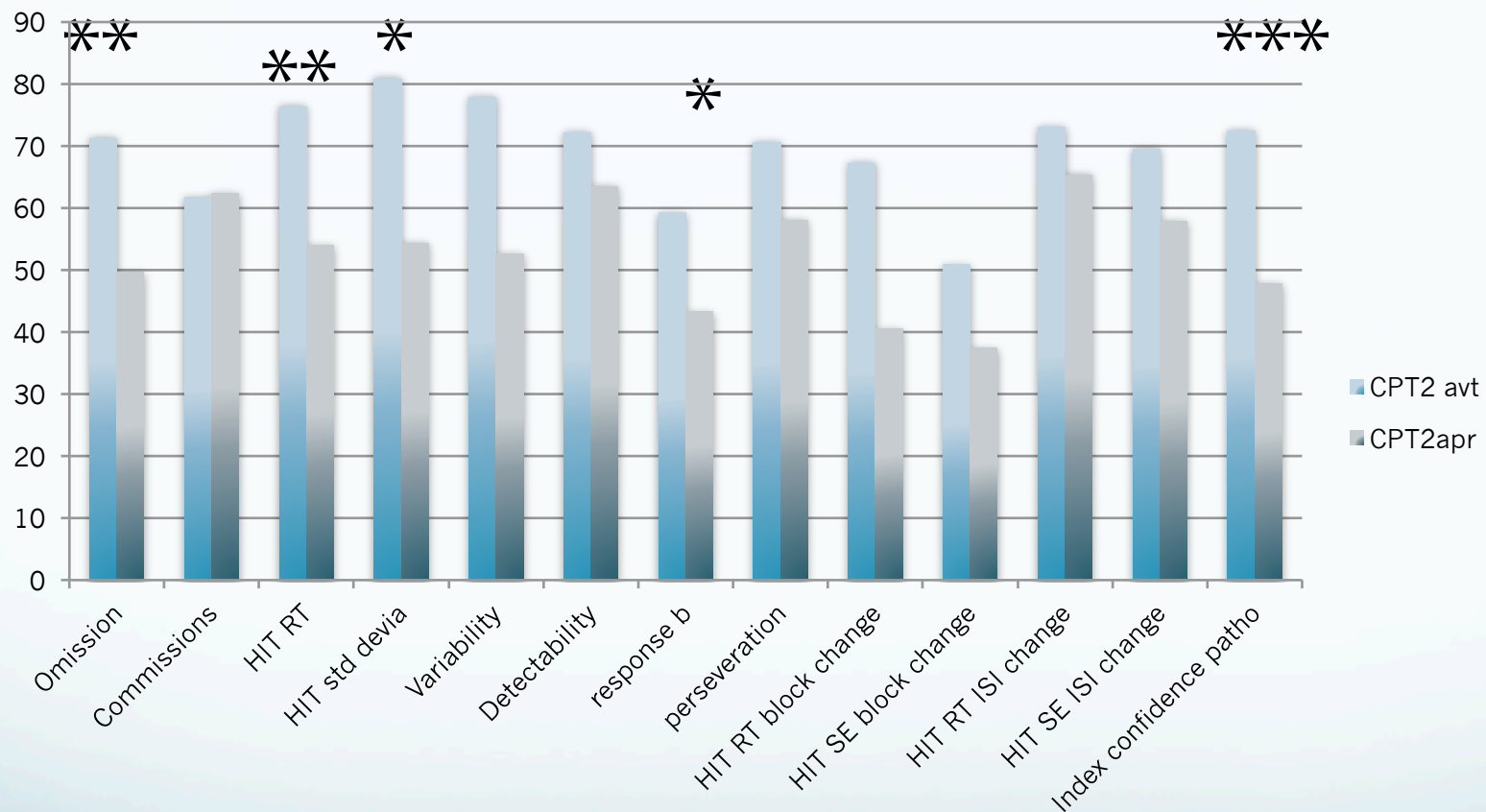




Performance moyenne en mémoire de travail : épreuve de mémoire de chiffres (MC) et épreuve séquence lettres chiffres (SLC), dans le groupe enfants et le groupe adulte.

Significativité des tests T : MC enf 0.00005; SLC enf 0.0019; MC adulte 0.0324; SLC adulte 0.0698.





Performance moyenne aux épreuves du CPT2 avant et après Cog-Med  
 \*  $p < 0.05$ ; \*\*  $p < 0.01$ ; \*\*\*  $p < 0.005$ . sous-groupe enfants (test de Wilconxon apparié).

# Remédiation cognitivo-musicale:

Une nouvelle voie dans le traitement des  
troubles spécifiques d'apprentissage

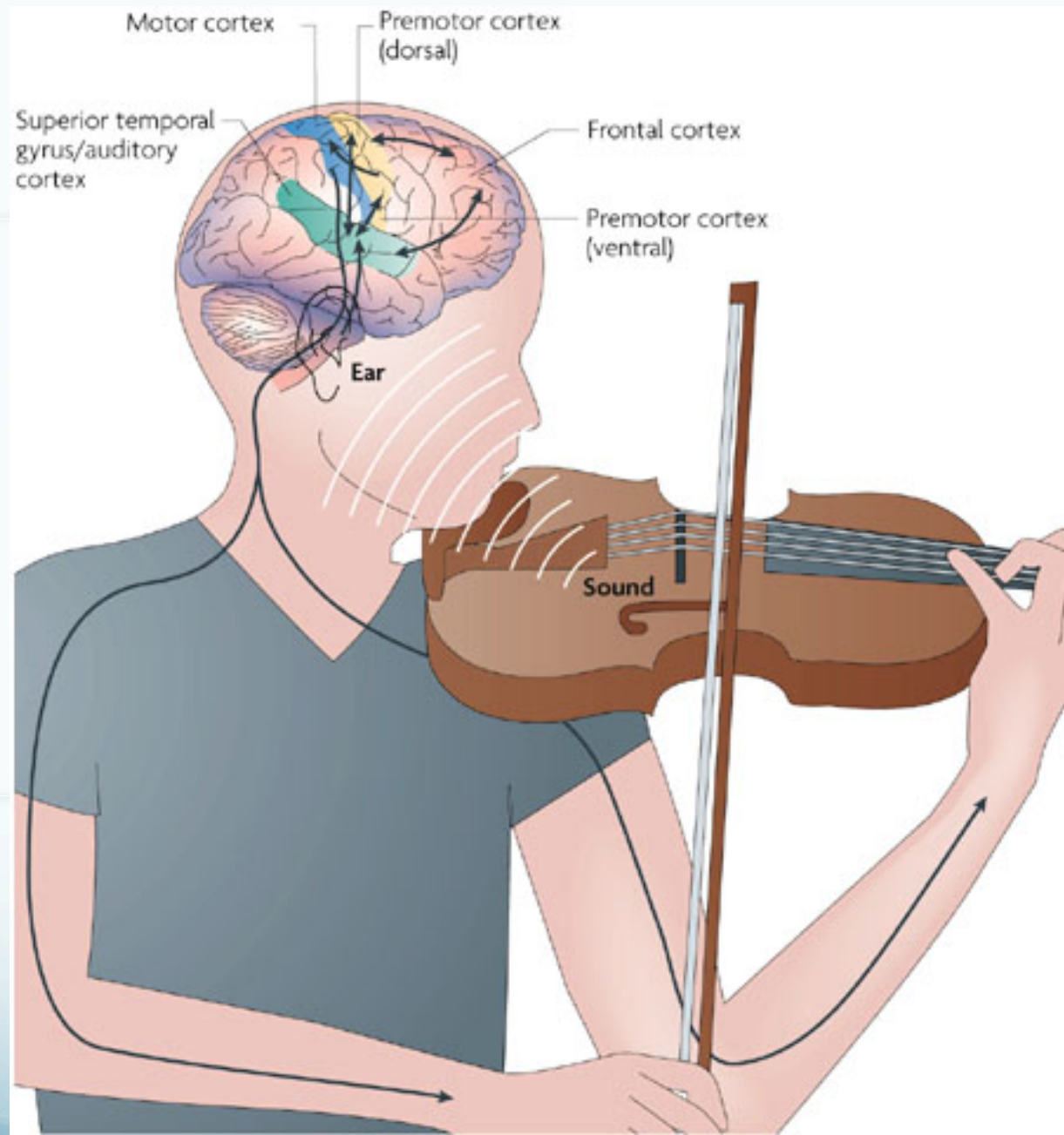
Céline Commeiras, Alice Dormoy & Michel Habib



<http://www.resodys.org>



<http://www.melodys.org/>



## Cortical Plasticity Induced by Short-Term Unimodal and Multimodal Musical Training

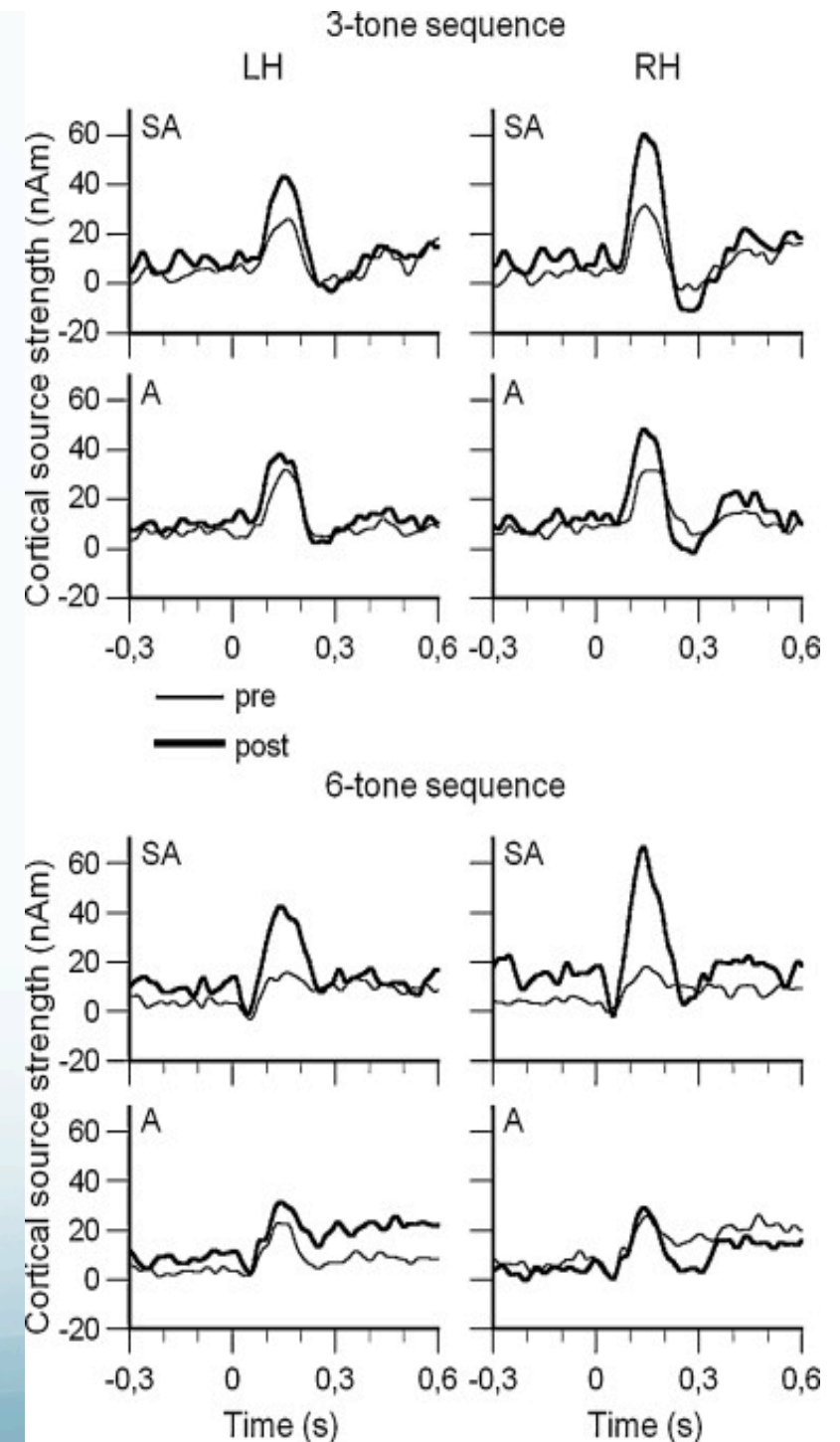
Claudia Lappe,<sup>1\*</sup> Sibylle C. Herholz,<sup>1\*</sup> Laurel J. Trainor,<sup>2,3</sup> and Christo Pantev<sup>1</sup>

<sup>1</sup>Institute for Biomagnetism and Biosignalanalysis, University of Münster, 48149 Münster, Germany, and <sup>2</sup>Department of Psychology, Neuroscience, and Behaviour and the <sup>3</sup>McMaster Institute for Music and the Mind, McMaster University, Hamilton, Ontario, Canada L8S 4K1



Enregistrement MEG avant et après 2 semaines d'entraînement chez deux groupes de non-musiciens : SA sensori-moteur + auditif (clavier) & A auditif

*multimodal sensorimotor-auditory training in non-musicians results in greater plastic changes in auditory cortex than auditory-*



# The enigma of dyslexic musicians

Atalia H. Weiss<sup>a,d,\*</sup>, Roni Y. Granot<sup>d</sup>, Merav Ahissar<sup>b,c</sup>

<sup>a</sup> Institute for Cognitive Science, Hebrew University, Mt. Scopus, Jerusalem 91905, Israel  
<sup>b</sup> Department of Psychology, Hebrew University, Mt. Scopus, Jerusalem 91905, Israel  
<sup>c</sup> Interdisciplinary Center for Neural Computation (ICNC), Hebrew University, Mt. Scopus, Jerusalem 91905, Israel  
<sup>d</sup> Department of Musicology, Hebrew University, Mt. Scopus, Jerusalem 91905, Is

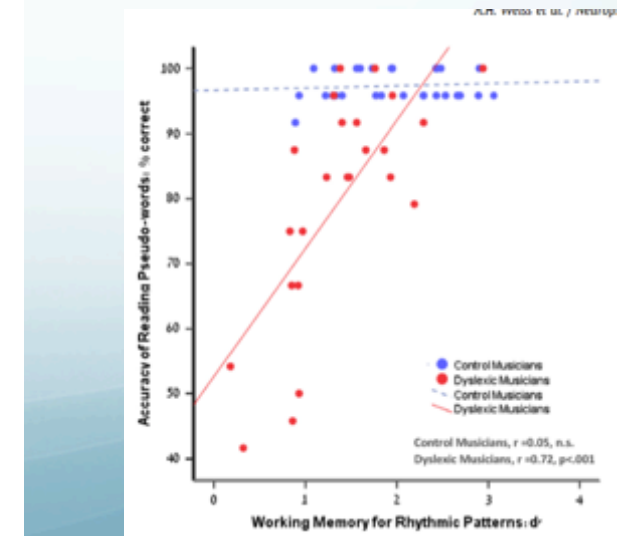
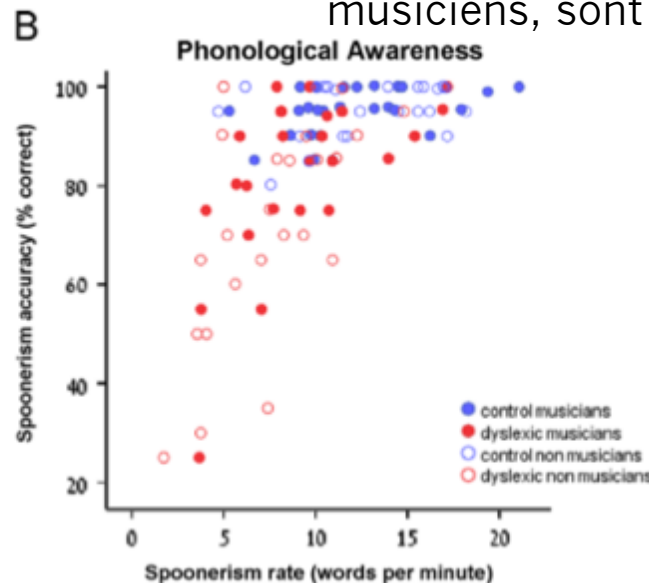
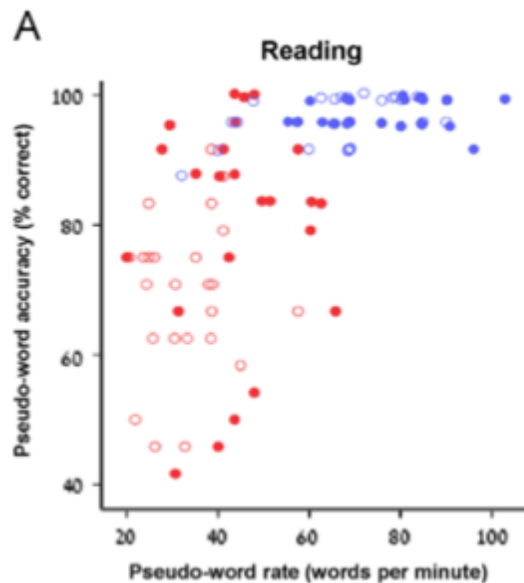
- 24 musiciens dyslexiques comparés
- à 24 dyslexiques non musiciens et
- 24 musiciens non dyslexiques
- > à ○ En lecture de pseudomots

+ à un moindre degré en phonologie

Means and STDs of cognitive and reading related measures for the four groups of participants.

	Musicians			Non-musicians			Scheffé post-hoc comparison	
	Controls	Dyslexics	t	Controls	Dyslexics	t	Control groups	Dyslexic groups
	n=28	n=24		n=23s	n=24			
	19F	9F		12F	18F			
Age (years)	23.5 (2.1)	23.7 (2.7)	-0.3	24.8 (3.7)	25.6 (2.5)	1.2	p=.487	p=.998
<b>Cognitive tests (scaled WAIS scores)</b>								
Block design	12.9 (2.0)	12.2 (2.6)	1.2	12.2 (2.8)	11.1 (2.5)	1.4	p=.798	p=.519
Digit span	11.6 (2.9)	9.7 (2.1)	2.6*	11.7 (2.4)	8.0 (1.8)	5.9***	p=.999	p=.101
<b>Reading accuracy (% correct)</b>								
Words	98.9 (1.8)	94.1 (6.0)	4.1***	99.3 (1.6)	92.0 (6.5)	5.2***	p=.996	p=.478
Pseudo words	97.3 (2.3)	79.8 (17.3)	5.3***	96.4 (4.0)	69.4 (11.9)	10.1***	p=.992	<b>p=.012*</b>
<b>Reading rate (words/min)</b>								
Paragraph	130.8 (13.4)	109.3 (25.3)	3.9**	-	-	-	-	-
Words	122.2 (21.2)	88.8 (28.5)	4.8***	114.3 (34.7)	69.4 (20.9)	5.5***	p=.772	p=.096
Pseudo-words	76.6 (12.4)	44.1 (11.7)	9.6***	65.9 (15.2)	33.1 (8.8)	9.0***	<b>P=.025*</b>	<b>P=.026*</b>
<b>Visual word recognition (words/min)</b>								
	70.1 (11.7)	53.4 (12.6)	4.8***	-	-	-	-	-
<b>Phonological awareness (spoonerism)</b>								
Accuracy (% correct)	95.1 (5.0)	81.6 (17.4)	3.9***	95.4 (5.6)	72.7 (21.7)	4.9***	p=1.0	p=.152
Rate (items/min)	12.3 (3.7)	9.1 (3.8)	2.9**	12.7 (3.8)	7.5 (3.2)	5.0***	p=.983	p=.505

Les meilleurs lecteurs, parmi les dyslexiques musiciens, sont ceux qui ont la meilleure MDT







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## OUR MISSION:

**TO PROMOTE** the positive development of children through music.

**TO BUILD** healthy communities.

**TO DEVELOP** children as ambassadors of peace, hope, and understanding.



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Samedi, 6 décembre

RESEARCH

09.03.14

## Music and the Developing Brain: Results from Our Partnership with Northwestern University

Some very exciting results were found in our research partnership with [Northwestern University](#)!

One research question Dr. Nina Kraus is trying to answer is "Can music offset the ever-widening academic gap between rich and poor?" Results of the research suggest that it does, and Harmony Project students are proving just that!

For the past three years, we've been working with Dr. Kraus and her team of researchers to study the

# Longitudinal Effects of Group Music Instruction on Literacy Skills in Low-Income Children

Jessica Slater<sup>1,2</sup>, Dana L. Strait<sup>1,3,4\*</sup>, Erika Skoe<sup>1,2,5\*</sup>, Samantha O'Connell<sup>1,6\*</sup>, Elaine Thompson<sup>1,2</sup>, Nina Kraus<sup>1,2,3,4,7\*</sup>

<sup>1</sup>Auditory Neuroscience Laboratory, Northwestern University, Evanston, Illinois, United States of America, <sup>2</sup>Department of Communication Sciences, Northwestern



November 2014 | Volume 9 | Issue 11 | e113383

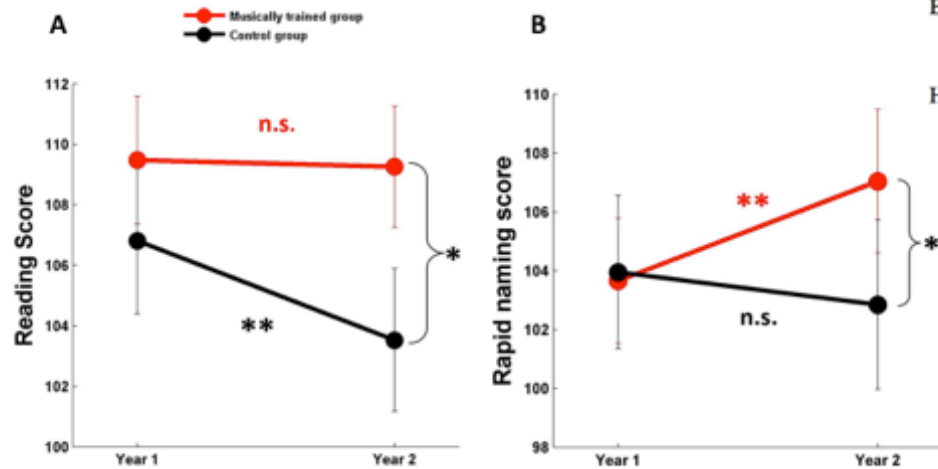


Figure 1. Music training supports reading abilities and rapid naming. (A) The children who received music training (n = 23) maintained their

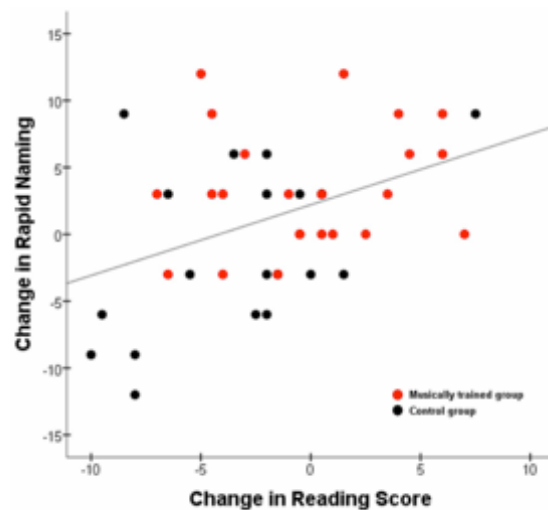


Figure 2. Improvement in rapid naming relates to reading improvement. Year-over-year improvement in rapid naming was correlated with the change in composite reading score across all participants (r = .413, p = .007, n = 43).

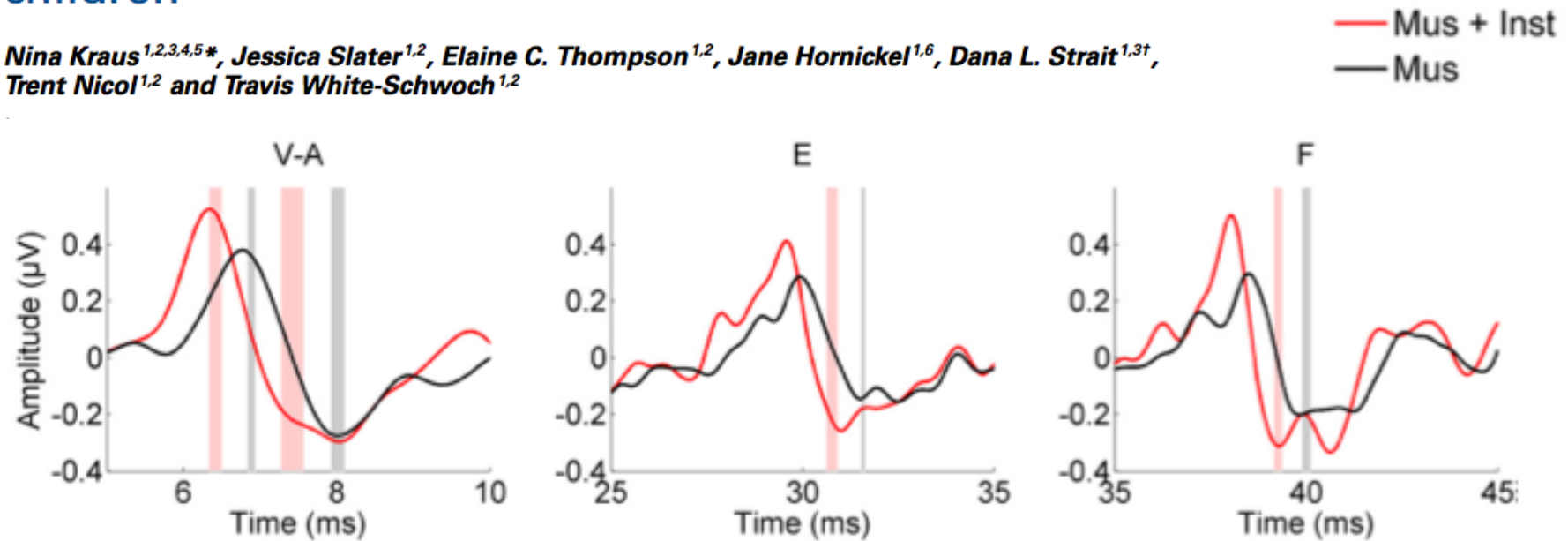
Harmony Project Program	Typical class participation	Number of children
Alexandria Elementary School	One-hour instrumental classes twice a week plus a two hour string ensemble rehearsal each week	3
Beyond the Bell	Twice-weekly two-hour ensemble rehearsals. These include pull-out sectional rehearsals, which are similar to large instrumental classes at other sites.	9
EXPO Center (YOLA)	One-hour instrumental music classes each week and a three hour ensemble rehearsal each week.	3
Hollywood	One-hour instrumental classes twice a week plus a three-hour ensemble rehearsal (concert band) each week.	4
		<b>19</b>

42 Spanish-English bilingual elementary school children (mean age 8.3 years) The training group (n=23) began music classes with the Harmony Project after the initial assessment, while the control children (n=19) remained on the organization's waiting list to begin music classes the following year.



# Auditory learning through active engagement with sound: biological impact of community music lessons in at-risk children

**Nina Kraus**<sup>1,2,3,4,5\*</sup>, **Jessica Slater**<sup>1,2</sup>, **Elaine C. Thompson**<sup>1,2</sup>, **Jane Hornickel**<sup>1,6</sup>, **Dana L. Strait**<sup>1,3†</sup>, **Trent Nicol**<sup>1,2</sup> and **Travis White-Schwoch**<sup>1,2</sup>



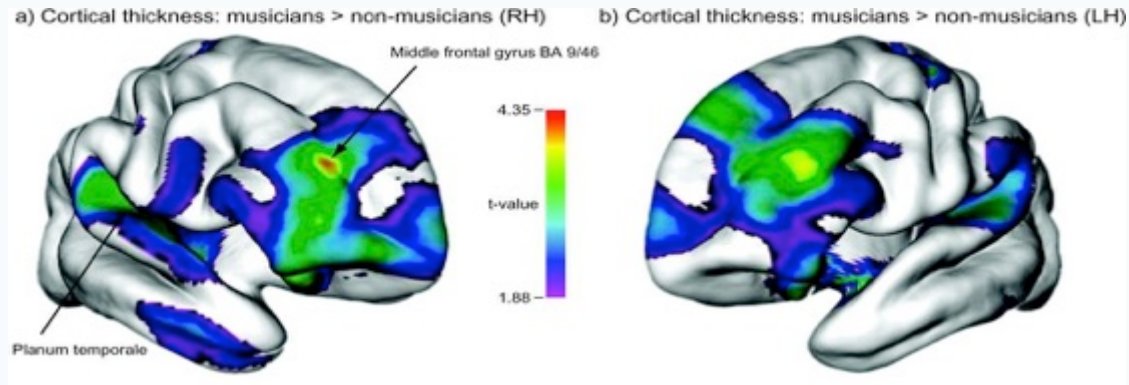
The “Mus” group comprised 10 children who spent the entire year in the “Music appreciation” class (described below). The “Mus+Inst” comprised nine children who participated in the “Music appreciation” during the first half of the year and matriculated to “Instrumental” classes for the second half of the year, after an appropriate number of instruments became available at that project site and/or instructors judged the students to be ready to progress in the program.

# La musique en tant qu'outil de restauration de la connectivité

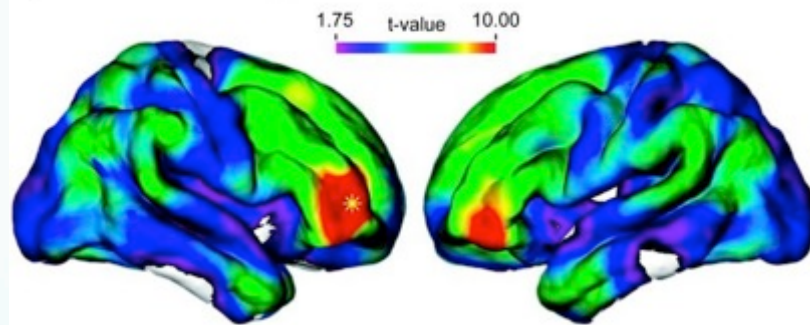
- Il existe un ensemble croissant et convergent d'arguments montrant que les troubles d'apprentissage sont associés du point de vue anatomique à des anomalies de connectivité entre des zones fonctionnelles de modalités différentes (en particulier hémisphériques gauches)
- ...et que l'entraînement rééducatif (en particulier phonologique) s'accompagne de remise en place des circuits anormalement connectés
- Par ailleurs, l'entraînement musical, et tout particulièrement l'apprentissage d'un instrument de musique, s'accompagne d'une modification de ces mêmes circuits, également surtout dans l'hémisphère gauche, un effet qui semble plus net lorsque les composantes motrice et sensorielle sont activées simultanément



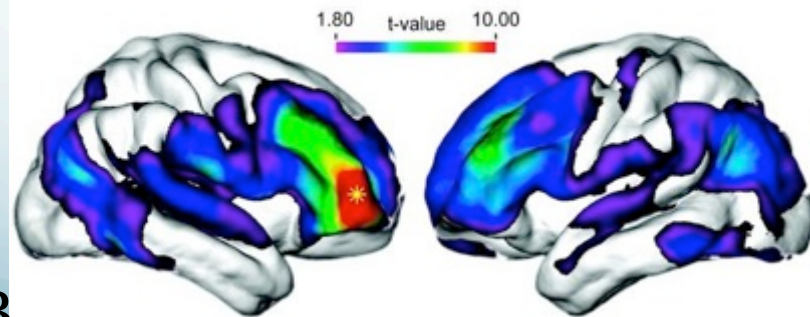
A.



a) non-musicians - right frontal seed 1



b) musicians - right frontal seed 1



B.

Bermudez P et al. *Cereb. Cortex* 2008, 19, 1985-1990

- A. Mesure de l'épaisseur corticale : différence entre musiciens > non musiciens
- B. Etude de corrélation entre une zone cible frontale droite et le reste du cerveau.
  - a) chez les non musiciens.
  - b) chez les musiciens : plus grande spécificité des connexions fronto-temporales reflétant l'interdépendance entre ces régions



# Short-Term Music Training Enhances Verbal Intelligence and Executive Function

Sylvain Moreno<sup>1</sup>, Ellen Bialystok<sup>2</sup>, Raluca Barac<sup>2</sup>,  
E. Glenn Schellenberg<sup>3</sup>, Nicholas J. Cepeda<sup>2,4</sup>,  
and Tom Chau<sup>3,5</sup>

<sup>1</sup>Rotman Research Institute, Toronto, Ontario, Canada; <sup>2</sup>Department of Psychology, York University;

Psychological Science  
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DOI: 10.1177/0956797611416999  
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SAGE

Un entraînement musical d'à peine 20 jours est capable de modifier durablement les capacités de flexibilité mentale et d'intelligence verbale

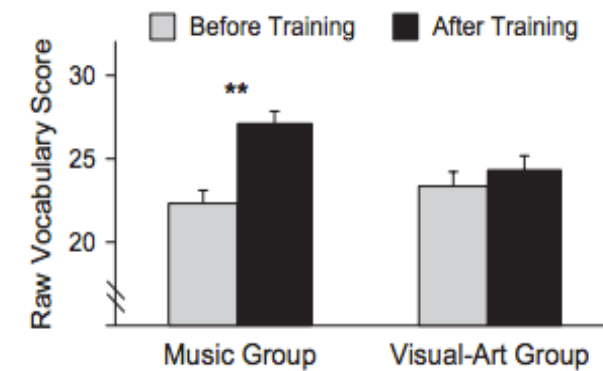
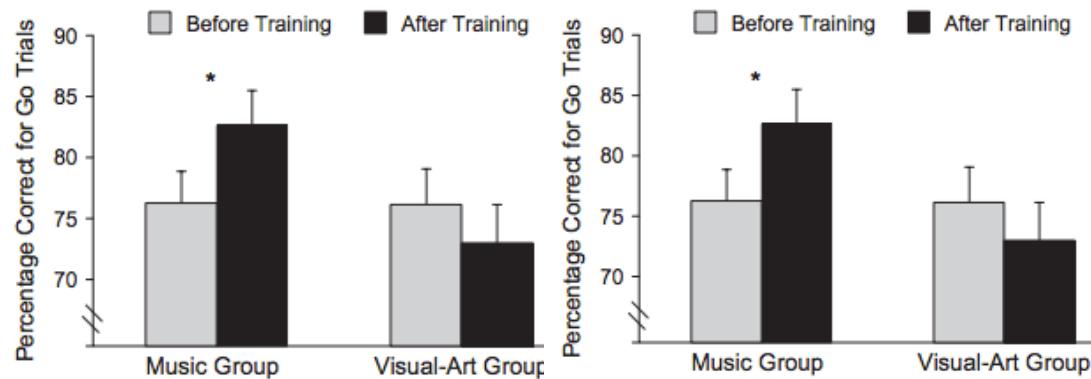
48 enfants 4-6 ans:

- 24 music group
- 24 : visual-art group

(2 programmes informatisés conçus pour l'occasion, parfaitement similaires en temps, nombre de sessions, difficulté attentionnelle)

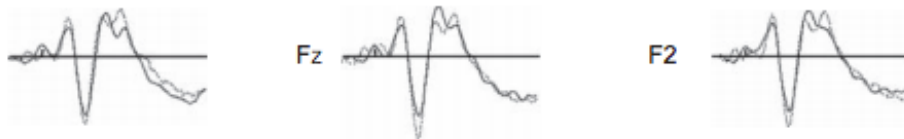
20 jours d'entraînement 45 mn/j.

Tâche go-nogo : appuyer pour les figures mauves, ne pas appuyer pour les blanches : deux mauves (carré triangle) deux blanches (carré, triangle)



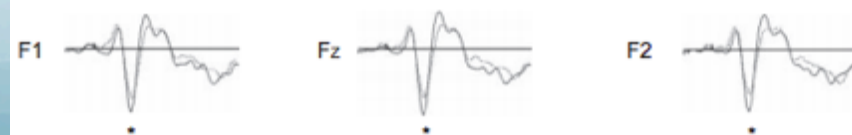
No-Go Trials Before Training

— Music Group    ... Visual-Art Group



No-Go Trials After Training

— Music Group    ... Visual-Art Group



# Music Training for the Development of Reading Skills

Adam Tierney<sup>\*†</sup>, Nina Kraus<sup>\*†,1,6\*,1</sup>

<sup>\*</sup>Auditory Neuroscience Laboratory, Northwestern University, Evanston, IL, USA

<sup>†</sup>Communication Sciences, Evanston, IL, USA

<sup>1</sup>Institute for Neuroscience, Evanston, IL, USA

<sup>2</sup>Neurobiology and Physiology, Evanston, IL, USA

<sup>3</sup>Otolaryngology, Evanston, IL, USA

<sup>4</sup>Corresponding author: Phone: +847-491-3181,

e-mail address: nkraus@northwestern.edu

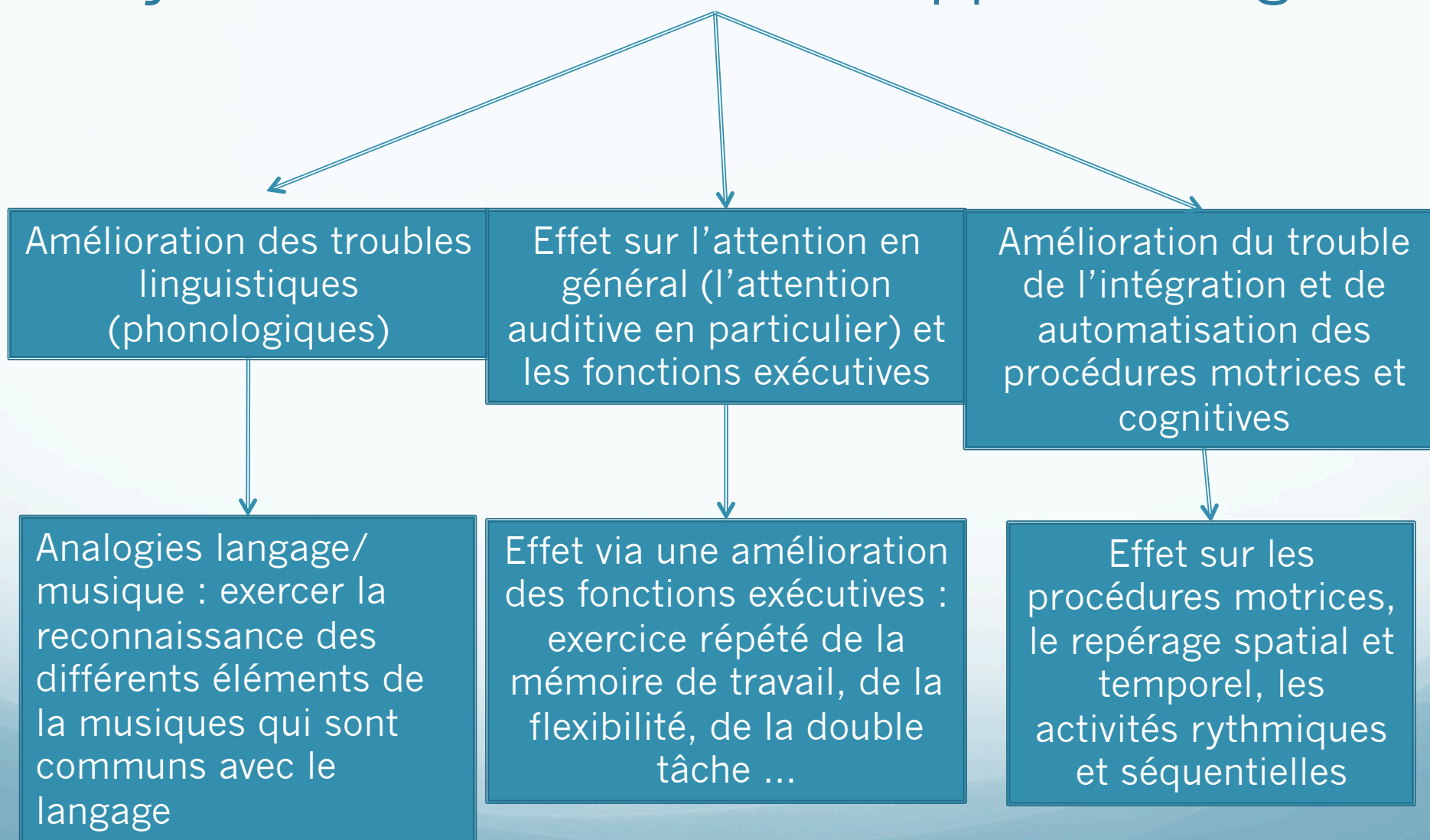
**Table 2** Summary of longitudinal studies of the effect of music training on reading ability and phonological awareness

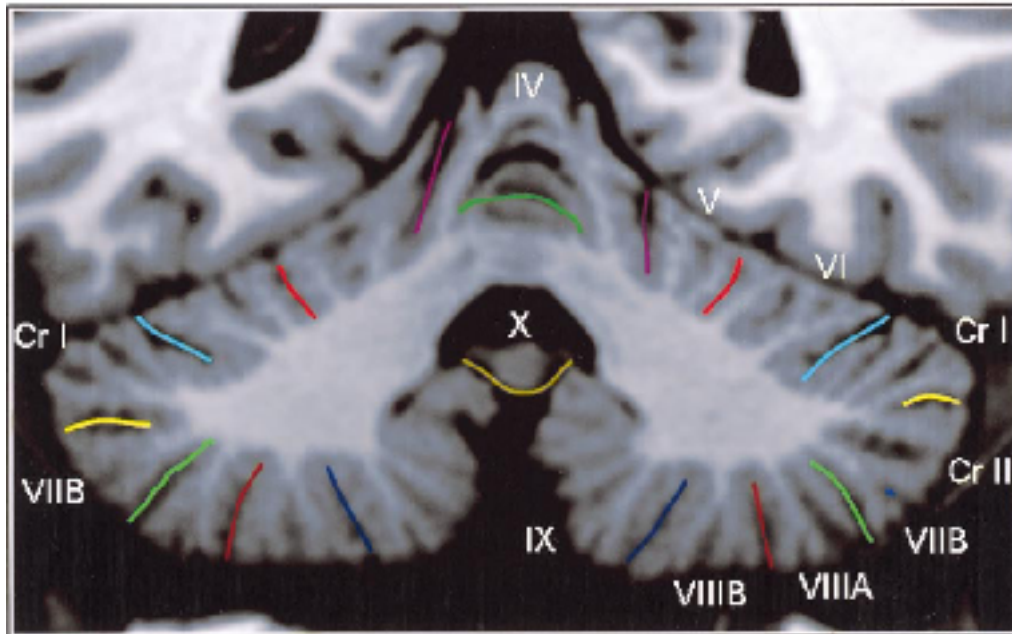
Study	Subjects	Music training	Control group	Improvements relative to control group
<b>Without random assignment</b>				
Hurwitz et al. (1975)	20 7-year-olds	Experimenter-designed	No training	Reading
Standley (1997)	32 4–5-year-olds	Experimenter-designed	No training	Pre-reading skills
Overy (2000, 2003)	9 dyslexic 9-year-olds	Experimenter-designed	None	Phonological awareness and spelling
Register (2004)	86 5–7-year-olds	Experimenter-designed to teach language skills	Literacy-training television show	None
Gromko (2005)	103 5-year-olds	Experimenter-designed	No training	Phoneme segmentation fluency
Rauscher and Hinton (2011)	75 5-year-olds	Private Suzuki violin instruction	Swimming lessons or no training	Word naming and phonemic awareness
Moritz et al. (2012)	30 5-year-olds	Preexisting school music classes	Less frequent music classes	Phonological awareness
Tierney et al. (2013)	43 adolescents	Preexisting school music classes	Fitness training	Earlier neural timing

## With random assignment

Roskam (1979)	36 learning-disabled 6–9-year-olds	Experimenter-designed	Learning disability rehabilitation	None
Douglas and Willatts (1994)	12 reading-disabled 9-year-olds	Experimenter-designed	No training	Reading
Fisher (2001)	80 5-year-olds	Experimenter-designed to teach language skills	Language skill teaching without music	Phoneme segmentation and oral skills
Costa-Giomi (2004)	80 fourth-graders	Private piano instruction	No training	None
Register et al. (2007)	33 second-graders, 6 reading-disabled	Experimenter-designed to teach reading skills	No training	Word knowledge
Forgeard et al. (2008)	44 6-year-olds	Unclear	No training	Word reading
Moreno et al. (2009)	32 8-year-olds	Computer-based	Painting or no training	Reading
Degé and Schwarzer (2011)	41 5–6-year-olds	Experimenter-designed	Phonological skill training	Phonological awareness
Herrera et al. (2010)	97 4-year-olds	Experimenter-designed to teach phonological skills	Phonological skill training or no training	Phonological awareness
Taub and Lazarus (2012)	280 students, age unclear	Synchronization to metronome	No training	Reading
Bhide et al. (2013)	19 poor readers, 6–7 years old	Computer-based rhythm training	Reading intervention	None
Cogo-Moreira et al. (2013)	240 poor readers, 9 years old	Experimenter-designed	No training	Reading and phonological awareness
Rautenberg (2013)	159 7-year-olds	Experimenter-designed	Visual arts training or no training	Word reading
Slater et al. (2013)	42 6–9-year-olds	Previously existing music program	No training	Reading

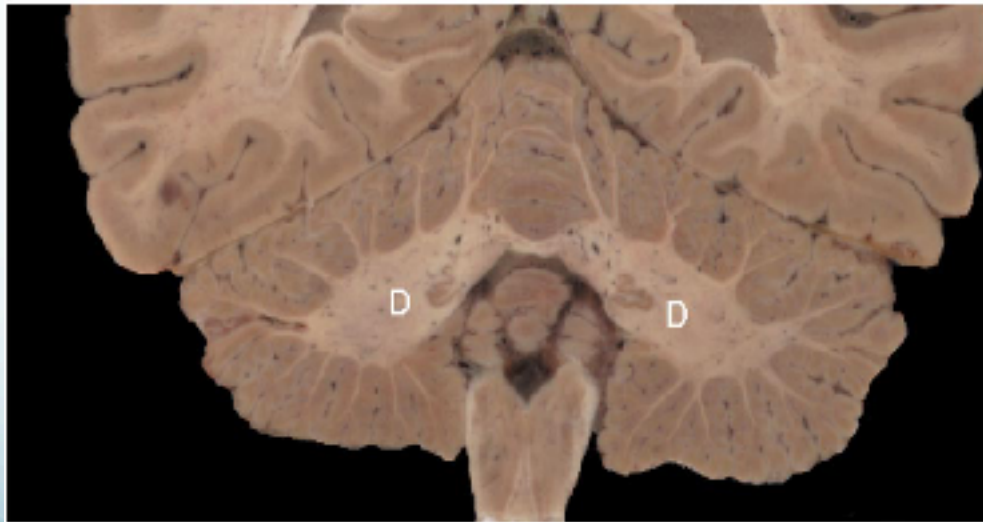
# Les effets possibles de la musique sur la dyslexie et les troubles d'apprentissage





## 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?

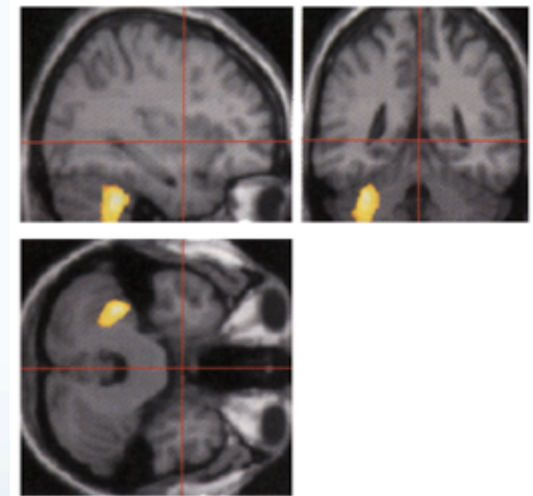




# Developmental dyslexia: the cerebellar deficit hypothesis

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

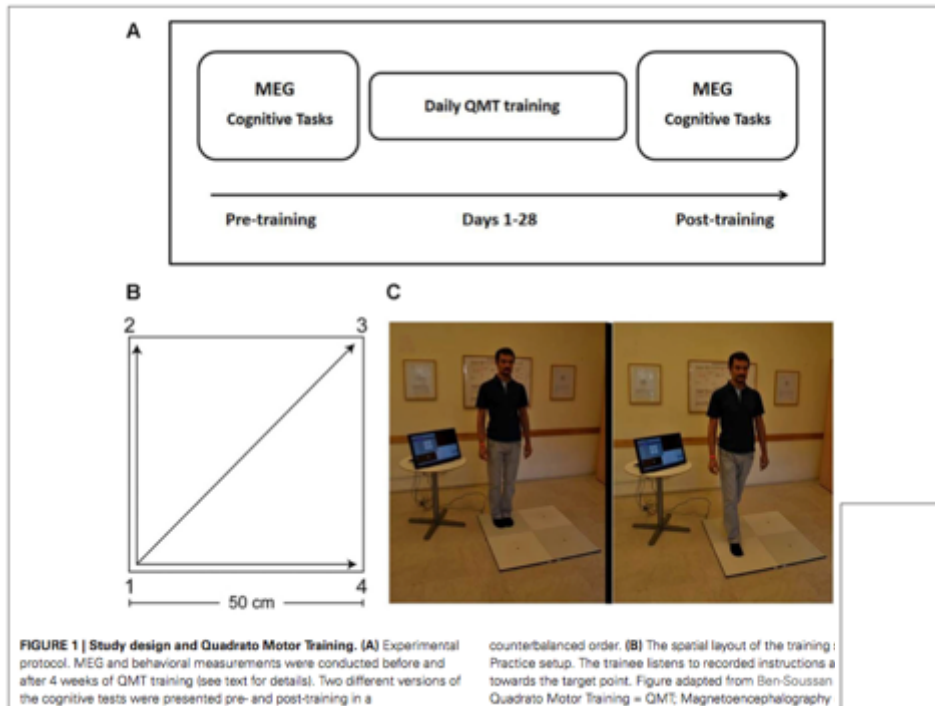
Nicolson et al., T.I.N.S., 2001



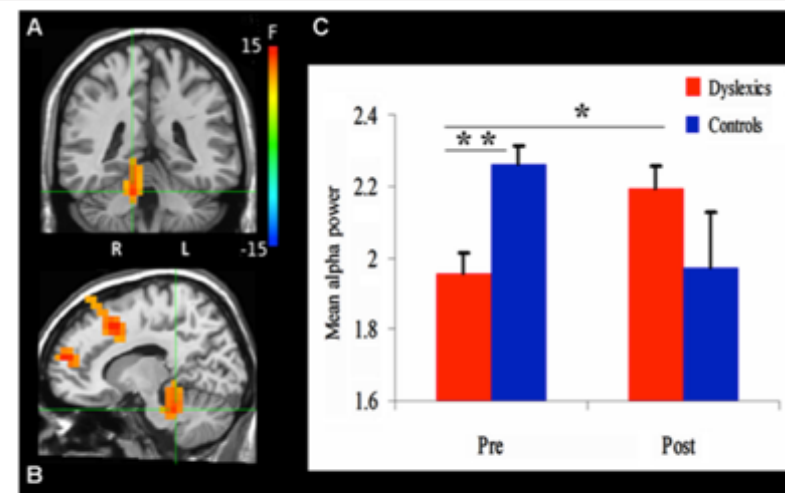


## Changes in cerebellar activity and inter-hemispheric coherence accompany improved reading performance following Quadrato Motor Training

Tal Dotan Ben-Soussan<sup>1,2,\*†</sup>, Keren Avirame<sup>1,3†</sup>, Joseph Glicksohn<sup>1,4</sup>, Abraham Goldstein<sup>1,5</sup>, Yuval Harpaz<sup>1</sup>



Twenty-two adult Hebrew readers (12 dyslexics and 10 controls) were recruited for the study. Using Magnetoencephalography (MEG), we measured changes in alpha power and coherence following QMT in a within-subject design. Reading performance was assessed pre- and post-training using a comprehensive battery of behavioral tests. Our results demonstrate improved performance on a speeded reading task following one month of intensive QMT in both the dyslexic and control groups. Dyslexic participants, but not controls, showed significant increase in cerebellar oscillatory alpha power following training.



**FIGURE 3 | Changes in alpha power.** (A) and (B) demonstrate the significant clusters resulting from the Group (dyslexics, controls) by Training (pre-training, post-training) interaction. Voxels are colored by the F statistics, overlaid on coronal (A) and sagittal (B) views. The statistical map is thresholded at  $p <$

0.0025 in addition to a cluster size threshold of 20 voxels. The focus point (green cross) is positioned in the right culmen (Talairach coordinate: 12, -37, -22). (C) The bar graph shows alpha power as a function of Group and Training (mean + SEM). \*  $p = 0.01$ ; \*\*  $p = 0.001$ .

## Timing precision and rhythm in developmental dyslexia

PETER H. WOLFF

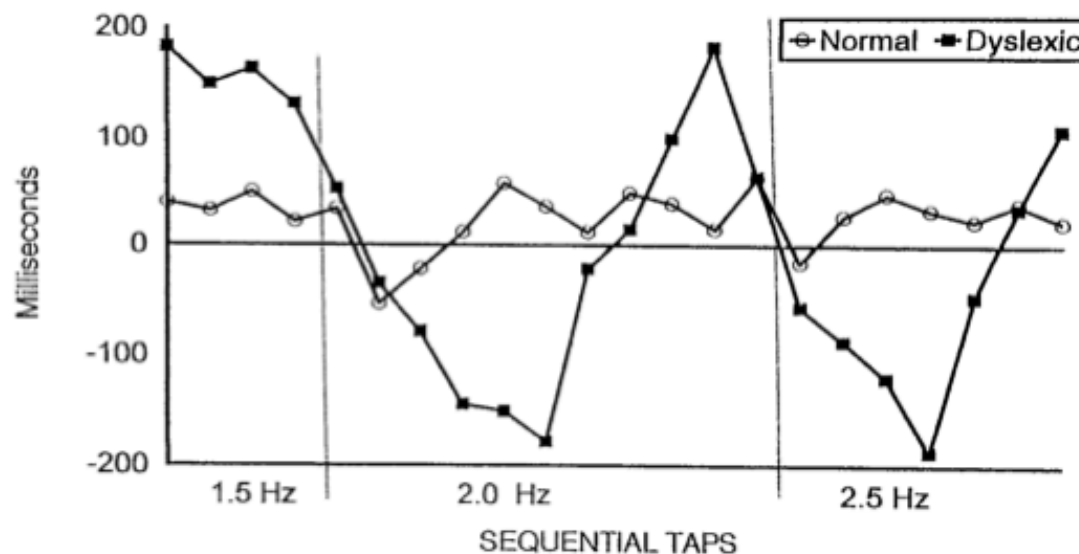
*Children's Hospital and Harvard Medical School, Boston MA 02115, USA*

dyslexic students anticipated the signal of an isochronic pacing metronome by intervals that were two or three times as long as those of age matched normal readers or normal adults. These group differences were significant when participants tapped with the preferred index finger alone or with both fingers in unison. Dyslexic students also took significantly longer than normal readers did to recalibrate their tapping responses when the metronome rate was experimentally changed in the middle of a trial. In addition, dyslexic students, by contrast to normal readers, had inordinate difficulty reproducing simple motor rhythms by finger tapping, and similar difficulty reproducing the appropriate speech rhythm of linguistically neutral nonsense syllables. These difficulties were exaggerated when participants had to synchronize their performance to an external pacing metronome.

**Table 2.** (A) Anticipation of isochronic intervals (finger tapping) and (B) Recalibration of anticipation mode (mean tracking responses before switch)

Outcome measure	Dyslexic students Mean (SD)	Normal readers Mean (SD)
<b>A. Absolute difference (ms) tap onset and metronome signal</b>		
Stable rate – 2Hz		
Right finger	130 (53)	41 (10)**
Both finger	86 (41)	28 (14)**
<b>B. Rate change: 1.5 to 2 Hz to 2.5 Hz</b>		
Right finger	6.1 (1.1)	1.3 (14)**

\*\* $p < 0.01$  Mann-Whitney U-Test.

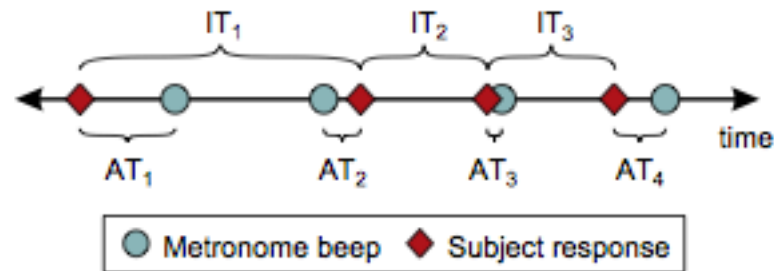


**Figure 1.** Mean intervals between tapping onset and metronome signal, before and after changes in metronome rate (dotted vertical lines). Points above the 0 line represent anticipations; those below the line represent tracking responses.



## Rhythmic processing in children with developmental dyslexia: Auditory and motor rhythms link to reading and spelling

Jennifer M. Thomson<sup>1</sup>, Usha Goswami<sup>\*</sup>



**Fig. 1 – Schematic depiction of ITI and AT calculation.**

CORTEX 45 (2009) 119–130

Special issue: Research report

### Rhythmic motor entrainment in children with speech and language impairments: Tapping to the beat

Kathleen H. Corriveau<sup>a,b</sup> and Usha Goswami<sup>a,\*</sup>

<sup>a</sup>Centre for Neuroscience in Education, University of Cambridge, Cambridge CB2 8PQ, UK

<sup>b</sup>Harvard University Graduate School of Education, Cambridge, MA, USA

We measure rhythmic finger tapping (paced by a metronome beat versus unpaced) and motor dexterity, phonological and auditory processing in 10-year old children, some of whom had a diagnosis of developmental dyslexia. We report links between paced motor tapping, auditory rhythmic processing and written language development. Motor dexterity does not explain these relationships. In regression analyses, paced finger tapping explained unique variance in reading and spelling.

Children with SLI were indeed found to be impaired in a range of measures of paced rhythmic tapping, but were not equally impaired in tapping in an unpaced control condition requiring an internally-generated rhythm. The severity of impairment in paced tapping was linked to language and literacy outcomes.



## Research report

## Music, rhythm, rise time perception and developmental dyslexia: Perception of musical meter predicts reading and phonology

Martina Huss, John P Verney, Tim Fosker, Natasha Mead and Usha Goswami\*



wav 002

♩ = 120

Accent sign

Lengthened by 166ms

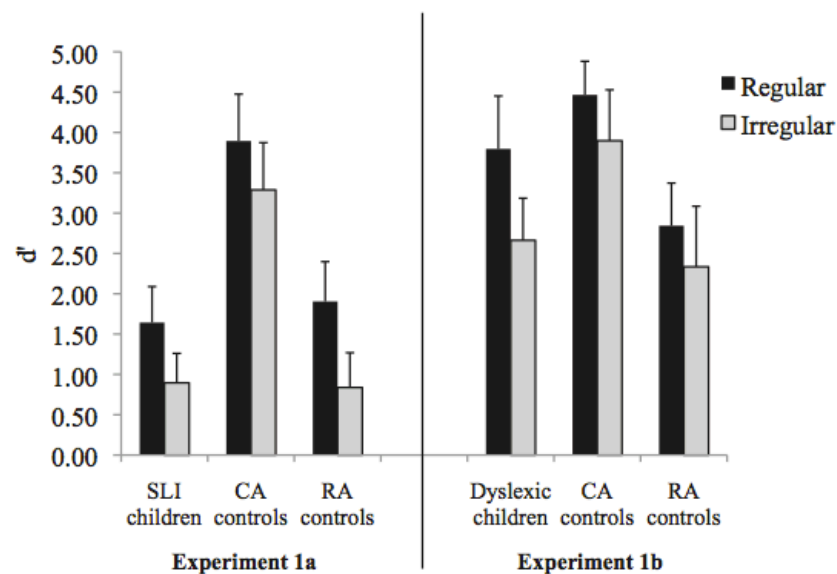
wav 008

Lengthened by 166ms

- Performances aux épreuves métriques corrélées aux tests phonologiques et de lecture
- Dyslexiques < contrôles sur toutes les épreuves métriques



## Rhythmic Auditory Stimulation Influences Syntactic Processing in Children With Developmental Language Disorders



*Figure 2.*  $d'$  data pattern of Experiments 1A and 1B averaged over participants, presented as a function of the musical prime (regular, irregular) and the participant groups: specific language impairment (SLI) children in Experiment 1A, dyslexic children in Experiment 1B, with their respective control groups matched for chronological age (CA) and reading age (RA). Error bars indicate between-participants standard errors.

Children listened to either regular or irregular musical prime sequences followed by blocks of grammatically correct and incorrect sentences. They were required to perform grammaticality judgments for each auditorily presented sentence (grammatical vs agrammatical).



Regular  
prime



Irregular  
prime



# Mise à l'épreuve de la théorie

Expériences utilisant l'entraînement intermodalitaire intensif à travers  
un apprentissage musical chez des enfants non musiciens

**Auteurs :**



**Michel Habib** est neurologue au CHU de Marseille, où il a exercé dans le domaine des troubles cognitifs de l'adulte et de l'enfant avant de se spécialiser progressivement dans les troubles d'apprentissage. Il enseigne la neuropsychologie dans plusieurs universités françaises et outre-Atlantique. Fondateur de la Revue de neuropsychologie, co-responsable de la revue *Développements*, et auteur de plusieurs ouvrages et articles, il a consacré ces dix dernières années à mettre en place un réseau de professionnels (RésoDys) autour de la dyslexie et des autres troubles d'apprentissage.



**Orthophoniste**, Céline Commeiras est responsable du pôle orthophonie au CPA-Provence et travaille en collaboration avec RésoDys depuis de nombreuses années. Maîtresse de stage d'étudiants en orthophonie de la faculté de Marseille, elle a également codirigé des mémoires de recherche sur la dyscalculie et le rôle de la musique dans la rééducation des enfants Dys.

La **rééducation par la musique** des personnes présentant des difficultés d'apprentissage n'est pas une idée nouvelle : depuis l'Antiquité, la musique fascine les observateurs par ses effets psychoaffectifs et le bien-être général qu'elle procure aux personnes qui l'écoutent.

La méthode présentée dans cet ouvrage ne se réclame pas de la musicothérapie, mais plutôt de la **rééducation fonctionnelle** : contrairement à la première, largement basée sur des constatations empiriques où le cerveau n'a qu'une place secondaire, le présent travail suit la démarche inverse, partant des données acquises par la **recherche en neurosciences** pour déboucher sur la construction d'outils de remédiation. Les auteurs proposent donc une véritable théorie du fonctionnement cérébral qui explique l'efficacité de la musique dans la rééducation.

Fondée sur du matériel musical, la méthode répond aux critères habituels de la **rééducation orthophonique**. Elle est, de ce fait, principalement destinée aux orthophonistes qui y trouveront une mine d'informations et d'idées pour leur tâche de rééducateur. Les thérapeutes et enseignants de diverses disciplines pourront également puiser dans ces pages des pistes et des outils transposables à leur pratique.

**Public :**

- Orthophonistes
- Ergothérapeutes
- Neuropsychologues
- Rééducateurs
- Psychomotriciens
- Professeurs de musique

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**Mélodys**

Michel Habib - Céline Commeiras

# Mélodys

## Remédiation cognitivo-musicale des troubles d'apprentissage

Michel Habib  
Céline Commeiras



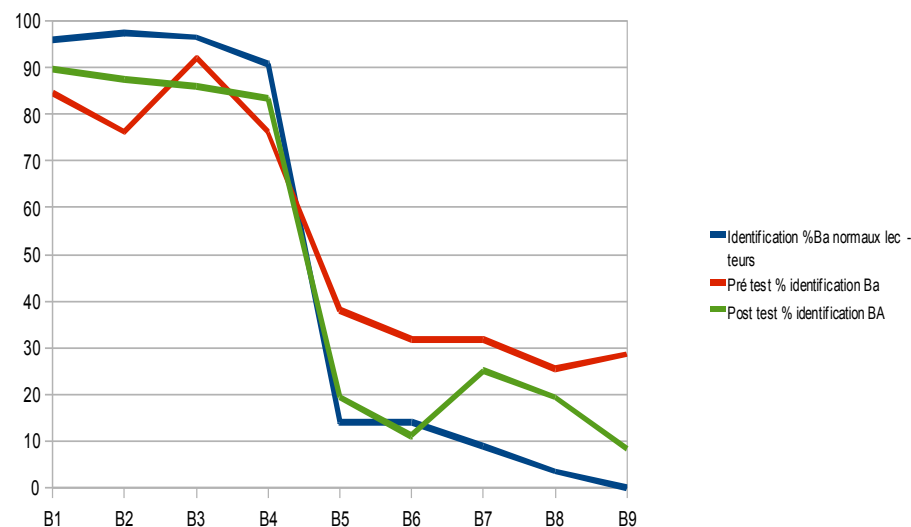
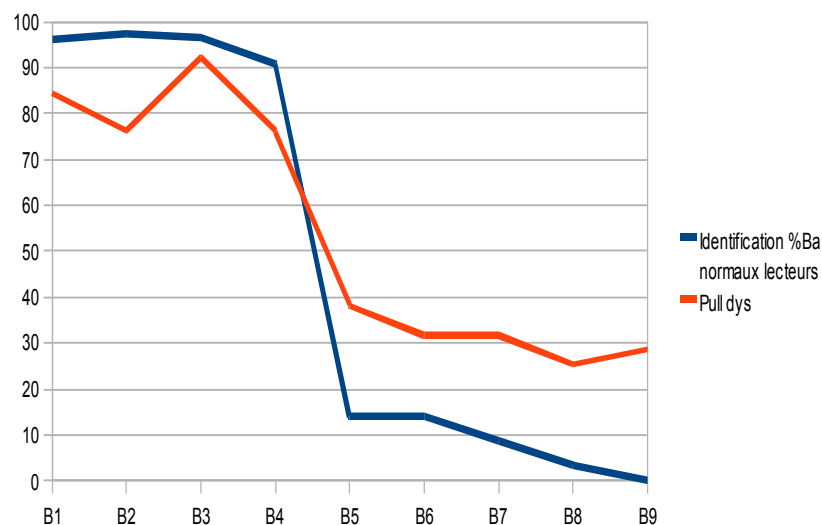
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# Etude préliminaire d'un entraînement musical intensif

- 12 enfants dyslexie sévère (multi-dys)
- 3 jours, 6 heures/jour 3 ateliers tournants (de 4)
  - Pédagogique : initiation au piano
  - Orthophonique : exercices auditifs (hauteur, durée, timbres, rythme)
  - Psychomoteur : percussions (rythme, tempo, motricité); danse folklorique de groupe
- Evaluation avant / après sur 3 tâches de perception des sons du langage : perception catégorielle, perception des durées, et perception de contours mélodiques altérés

# Résultats préliminaires : effet sur une épreuve de perception catégorielle ba/pa

ANOVA à mesures répétées  
 $F(1,21)=2,8; p=0.0051$



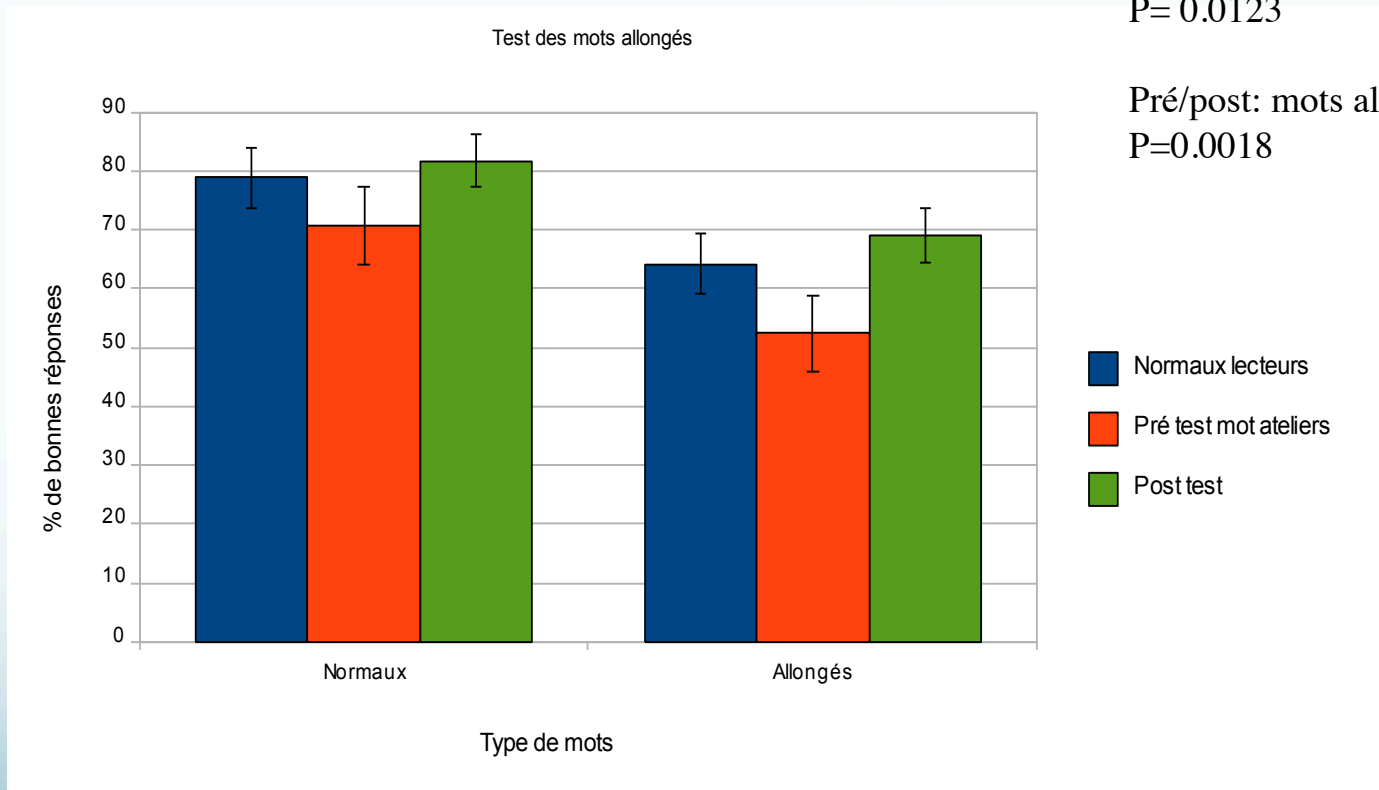
Comparaison avant/après atelier rééducatif :

- amélioration perception intra-catégorielle (moins de perception allophonique)
- amélioration perception inter-catégorielle (restitution de la pente de la frontière inter-catégorielle)

# Test de repérage de syllabes allongées

Pré/post : mots normaux  
P= 0.0123

Pré/post: mots allongés  
P=0.0018





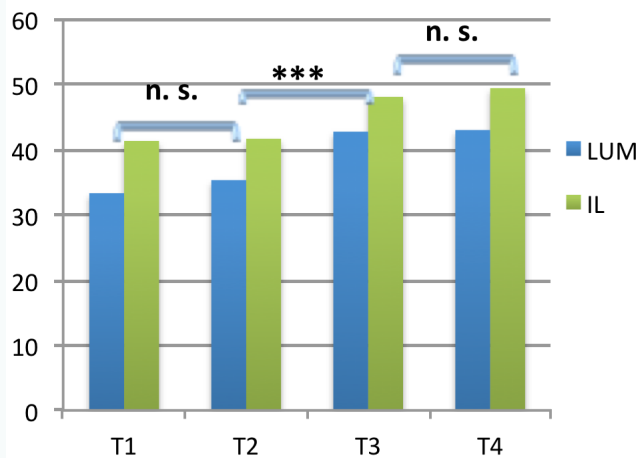
# En résumé

- Un entraînement intensif de 6 heures par jour chez des enfants sévèrement dyslexiques (multi-dys) a permis une amélioration significative d'un déficit préalablement établi dans deux domaines du traitement des sons du langage : la perception catégorielle du voisement et la perception de la durée de syllabes
- Questions à résoudre :
  - Peut-on obtenir des résultats similaires avec un protocole de durée identique mais étalé sur plusieurs semaines?
  - Les effets obtenus sont-ils généralisables à des fonctions cognitives plus générales?
  - Sont-ils durables après l'arrêt de l'entraînement?

## Etude n°2 : dyslexiques en CLIS

- 12 enfants âgés de 7 à 12 ans, tous atteints d'un trouble spécifique du langage et/ou de la parole
- 4 filles 8 garçons
- Sur 6 semaines : deux séances d'orthophonie ou remédiation cognitivo-musicale d'une heure chacune en classe entière (12 enfants) puis deux ateliers musicaux d'une demi-heure : piano et percussion par groupe de quatre enfants.
- 4 mesures T1, T2, T3, T4 : entraînement entre T2 et T3 + deux périodes contrôles

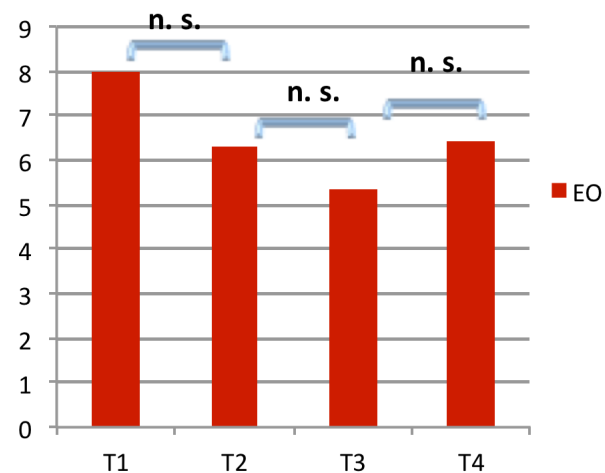
### Scores de lecture en une minute (LUM), et items lus (IL)



\*\*\* :  $p < 0,001$  ; \*\* :  $p < 0,01$  ; \* :  $p < 0,05$  ; + :  $p < 0,1$  ; n.s: non significatif

**Figure 12 : Histogramme illustrant les scores moyens obtenus pour (LUM) et (IL) pour les 4 mesures.** Amélioration significative pour (LUM) entre T2 et T3 ( $t = -5.583$  ;  $p = 0.0002$ ), et pour (IL) entre T2 et T3 ( $t = 7.489$  ;  $p < 0.0001$ ) ; non significative entre T1 et T2 et entre T3 et T4.

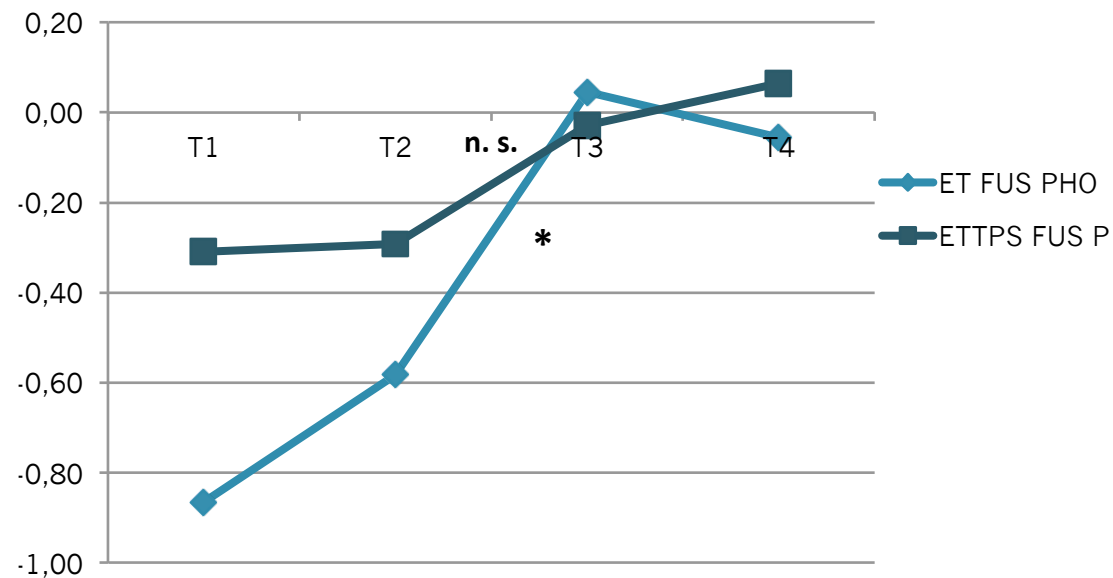
### Erreurs d'oralisation (EO)



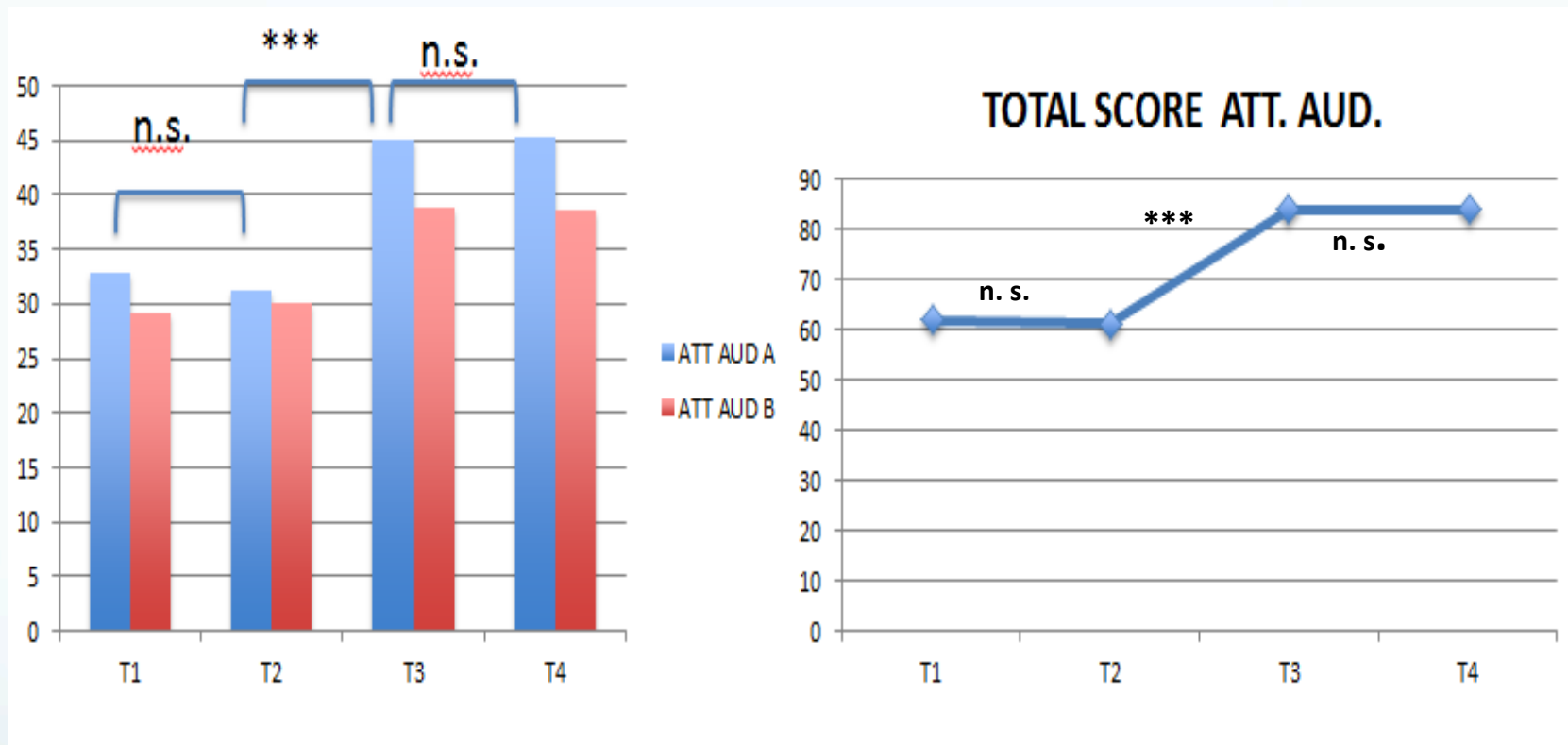
\*\*\* :  $p < 0,001$  ; \*\* :  $p < 0,01$  ; \* :  $p < 0,05$  ; + :  $p < 0,1$  ; n.s: non significatif

**Figure 13 : Histogramme illustrant les scores moyens obtenus pour (EO) pour chacune des 4 mesures.** Résultats non significatifs malgré le recul du nombre d'erreurs à T3 .

### Conscience phonologique (écart type) qualité et vitesse de fusion phonémique



Amélioration significative pour l'exactitude de la fusion phonémique entre T2 et T3 ( $t=-2.901$ ;  $p=0.0144$ ), non significative entre T1 et T2 et entre T3 et T4. Résultats non-significatifs pour les écarts types de vitesse



**Scores attention auditive  
soutenue (A), attention auditive  
divisée (B)**

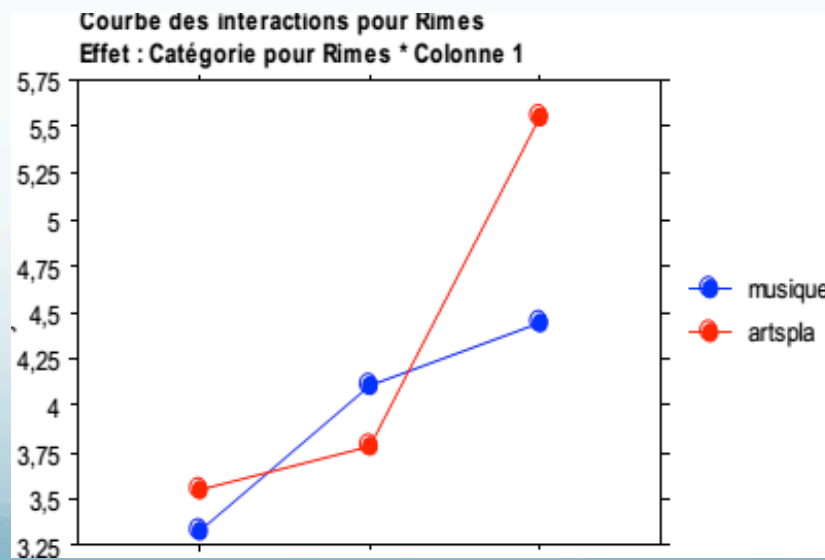
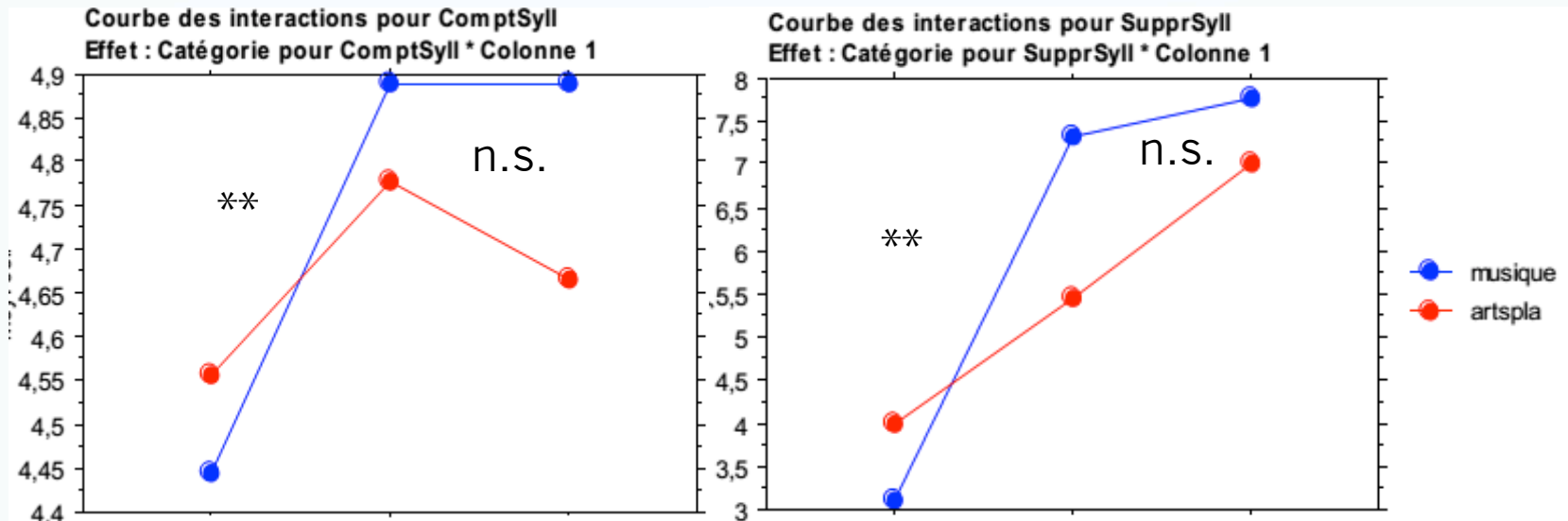


# Etude n°3 : précurseurs de la lecture en maternelle

- 14 garçons et 10 filles, âgés de 4 ans 10 mois à 5 ans 9 mois.

		Dates	Durée
Bilan pré-entraînement	B1	23/09/13 au 4/10/13	2 semaines
Entraînement Musical / Arts Plastiques		18/10/13 au 31/01/14	12 semaines
Bilan 2	B2	03/02/14 au 14/02/14	2 semaines
Aucune intervention musicale		01/02/14 au 01/04/14	8 semaines
Bilan 3	B3	01/04/14 au 11/04/14	2 semaines

# Tests de conscience phonologique



# En résumé

- Un entraînement intensif de 18 heures, qu'il soit groupé sur 3 jours ou étalé sur 5-6 semaines, améliore de façon significative des variables linguistiques non entraînées
- Par comparaison à une période sans entraînement, un effet significatif de l'entraînement est retrouvé sur diverses mesures directement impliquées dans les apprentissages scolaires (phonologie, lecture, attention auditive, mémoire de travail)
- Comme pour des enfants dyslexiques de primaire, des enfants de maternelle, sans pathologie avérée, mais provenant d'un milieu socialement fragile, améliorent également leurs performances en phonologie et en mémoire de travail.

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