

Inserm



CENIR
Centre de Neuroimagerie de
Recherche - Paris

UPMC
PARIS UNIVERSITAS

L'image du traumatisme crânien léger *à la croisée de la physiologie et la psychologie*

Arnaud Messé, PhD



Universitätsklinikum
Hamburg-Eppendorf

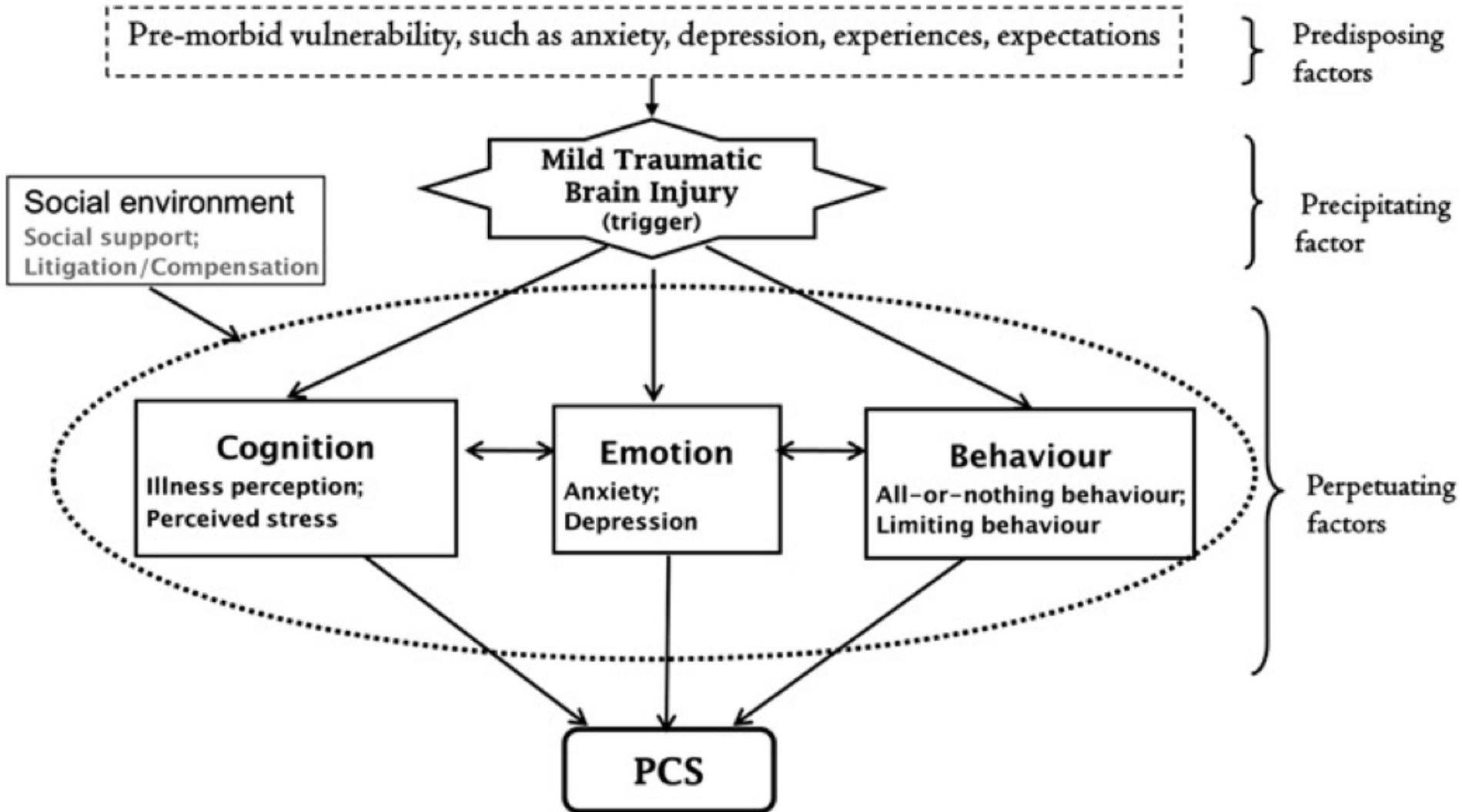


*Inserm, UPMC Univ Paris 06, UMRS 678, Laboratoire d'Imagerie Fonctionnelle, Paris
Department of Computational Neuroscience, Universitätsklinikum Hamburg-Eppendorf, Hamburg*

**Syndrome post-commotionnel
dans le traumatisme crânien léger**
Biomarqueurs et facteurs pronostics

Arnaud Messé, PhD

Le syndrome post-commotionnel



“*L'épidémie silencieuse (handicap invisible)*”

- Trauma léger ~ 80%
 - ~120 000 / an en France (1–3/1000)
 - ~1.5 million / an aux Etats-Unis (5/1000)
- Syndrome persistant chez 10 à 20 % des traumas légers
- Problème de santé publique
 - d'ordre socio-professionnel et socio-économique
 - ~ 60 milliards de dollars par an aux Etats-Unis pour les traumas

“L'épidémie silencieuse (handicap invisible)”

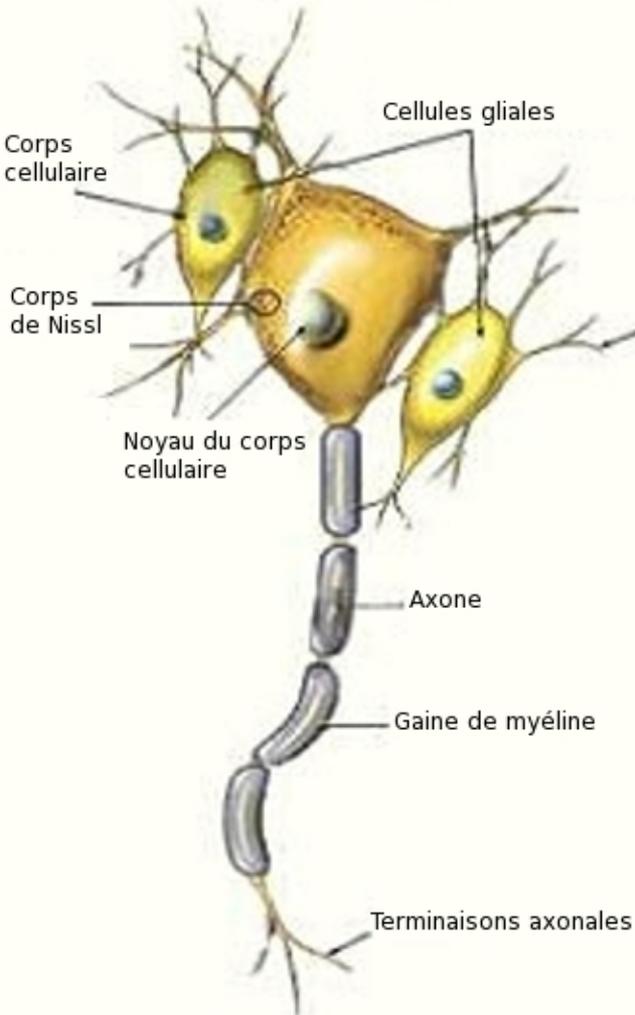
- Trauma léger ~ 80%
 - ~120 000 / an en France (1–3/1000)
 - ~1.5 million / an aux Etats-Unis (5/1000)
- Syndrome persistant chez 10 à 20 % des traumas légers
- Problème de santé publique
 - d'ordre socio-professionnel et socio-économique
 - ~ 60 milliards de dollars par an aux Etats-Unis pour les traumas

Origine physiologique, psychogène?

Prédiction?

Les lésions axonales diffuses

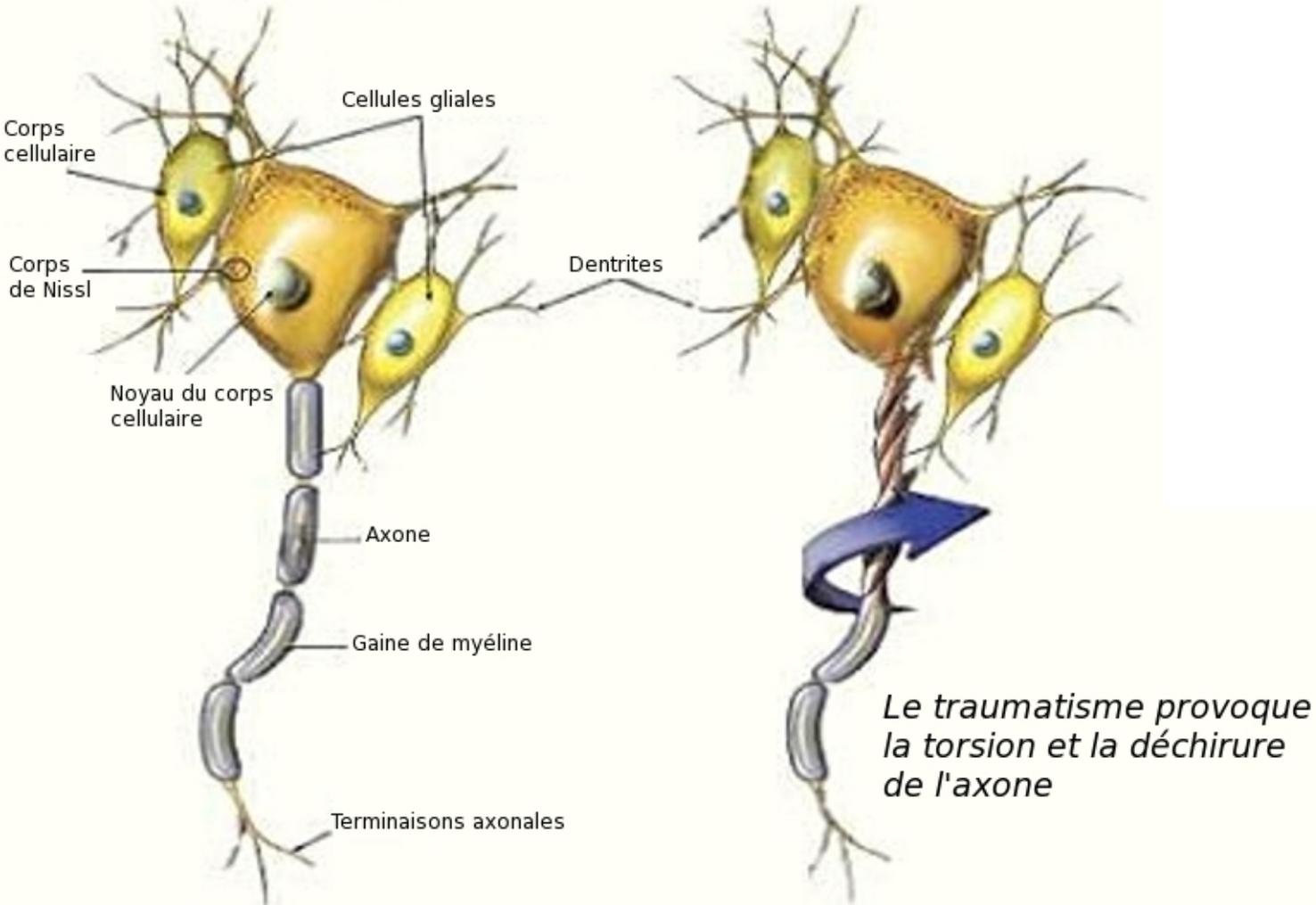
Axone normal



Les lésions axonales diffuses

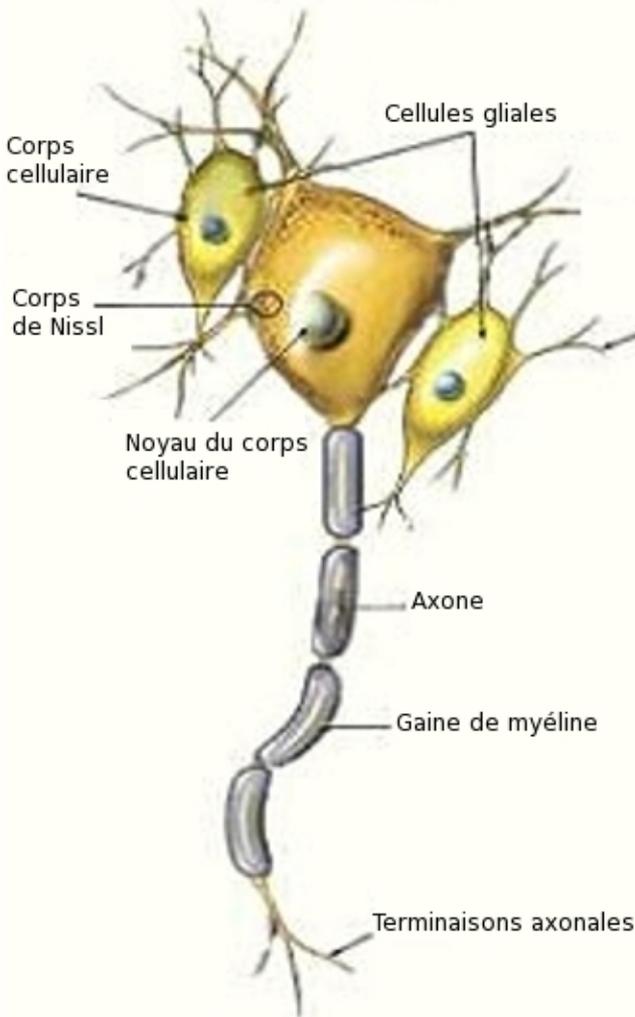
Axone normal

Cisaillement de l'axone

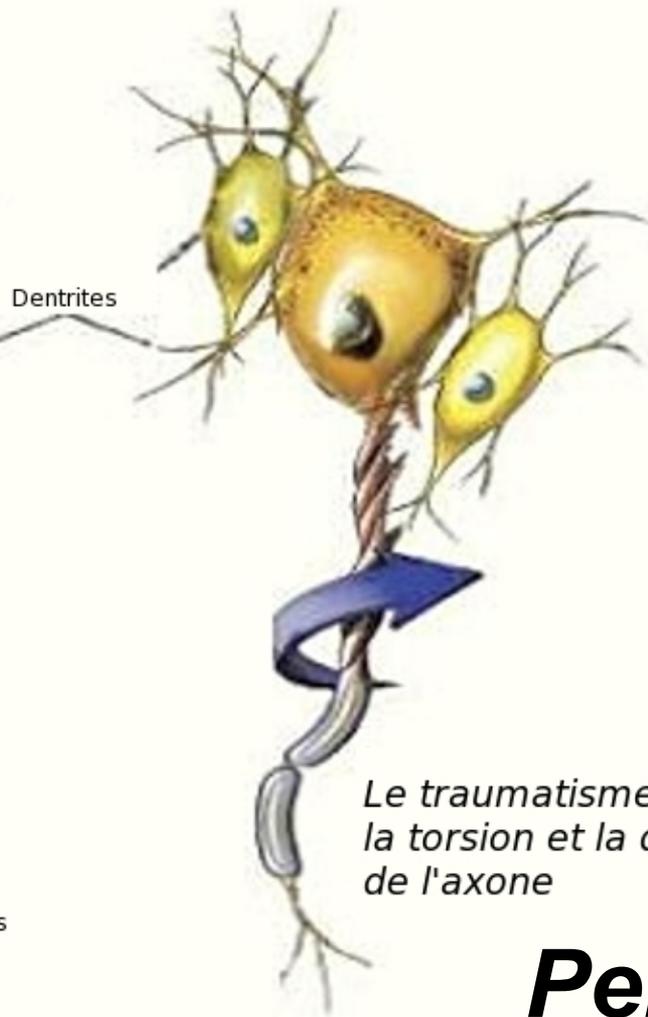


Les lésions axonales diffuses

Axone normal



Cisaillement de l'axone

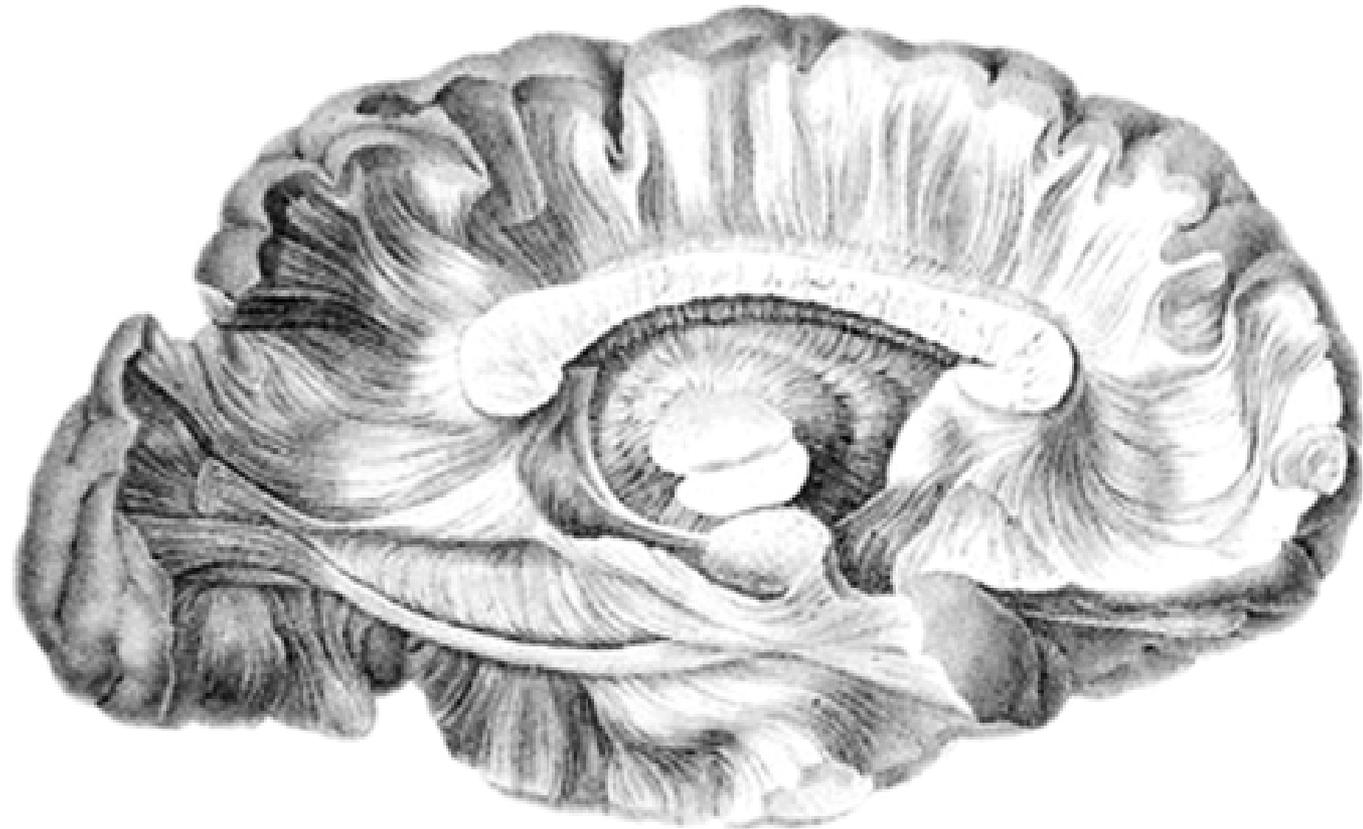
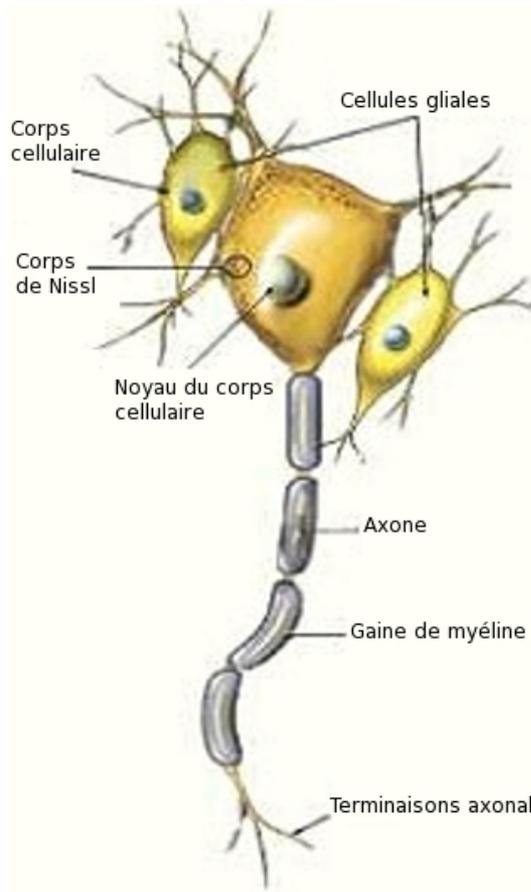


Après le traumatisme

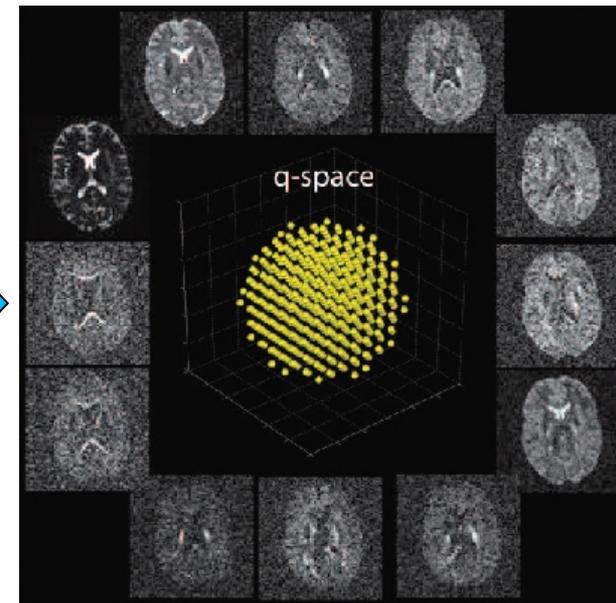
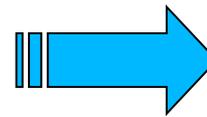
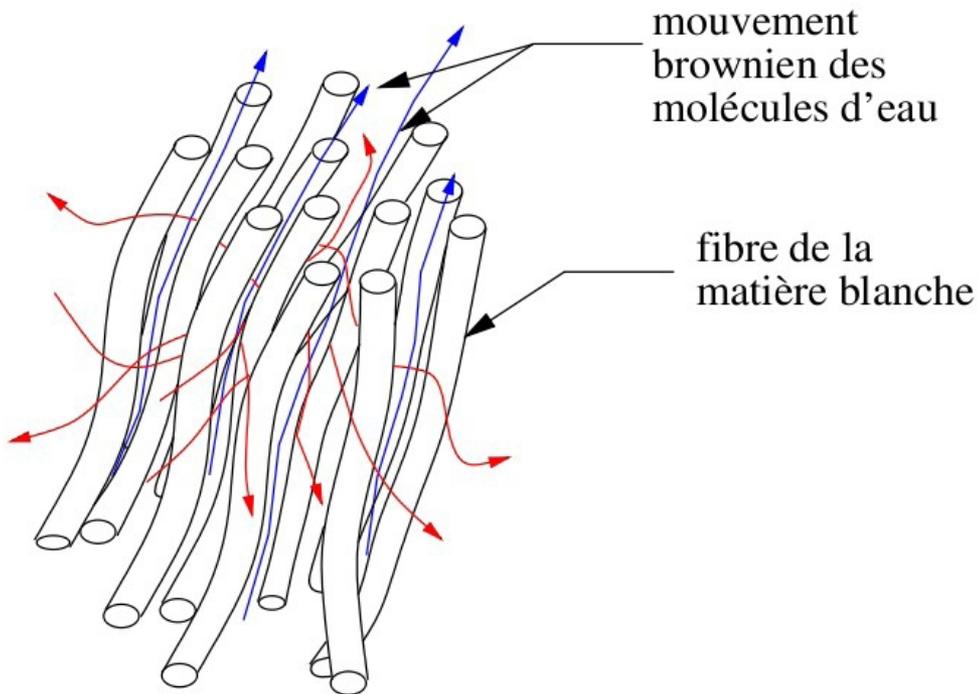
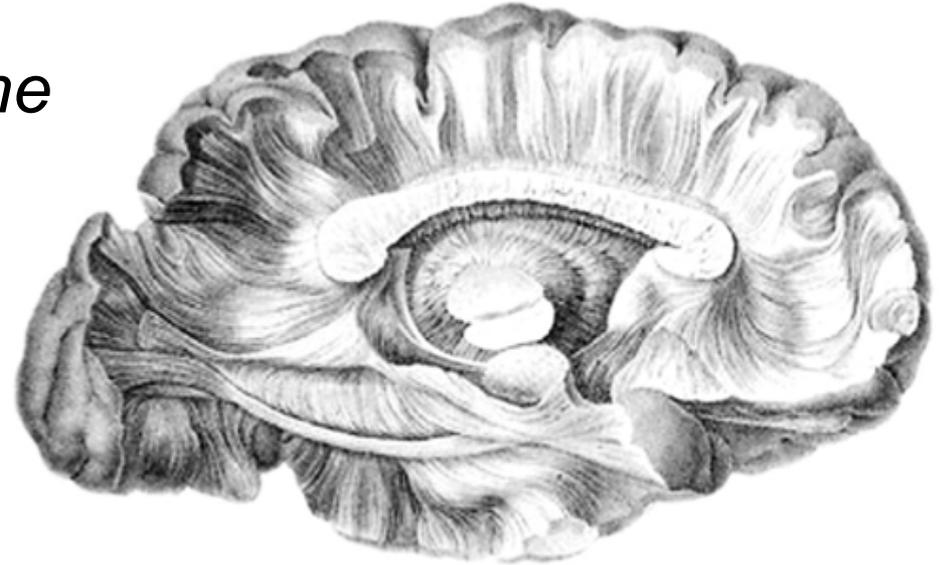


Perte d'intégrité

Structure de la matière blanche

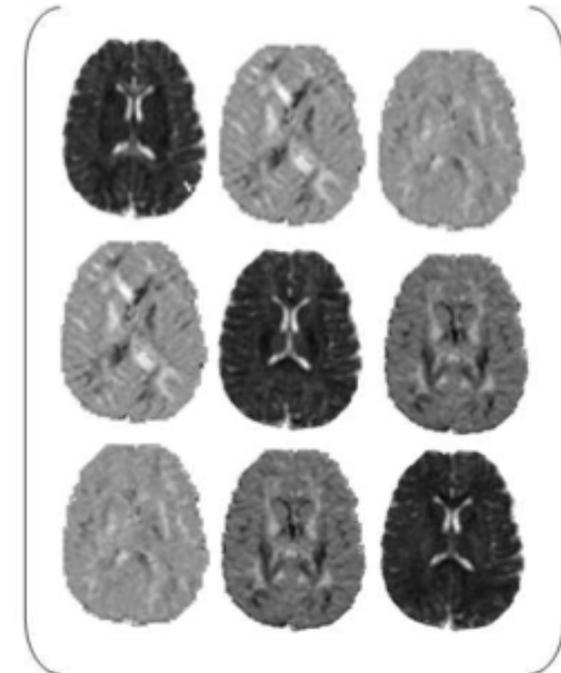
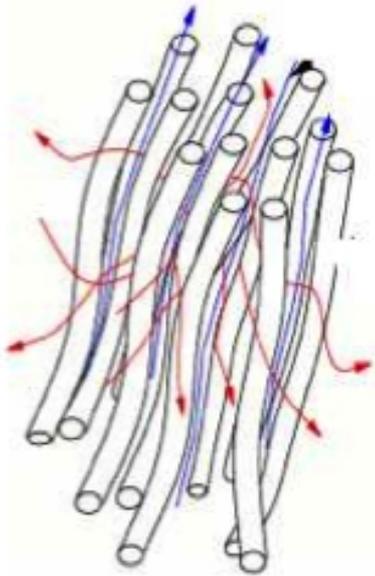
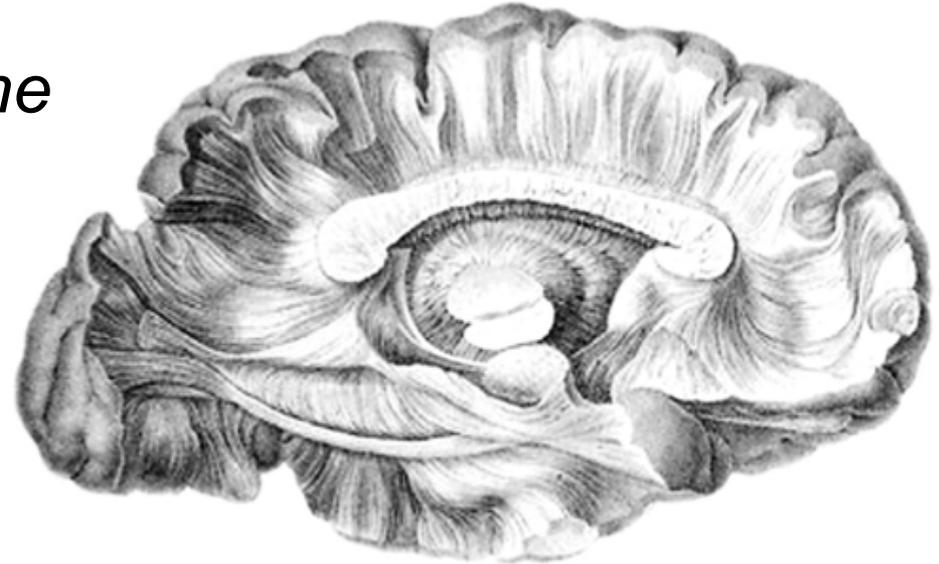


Structure de la matière blanche



Structure de la matière blanche

Le tenseur de diffusion

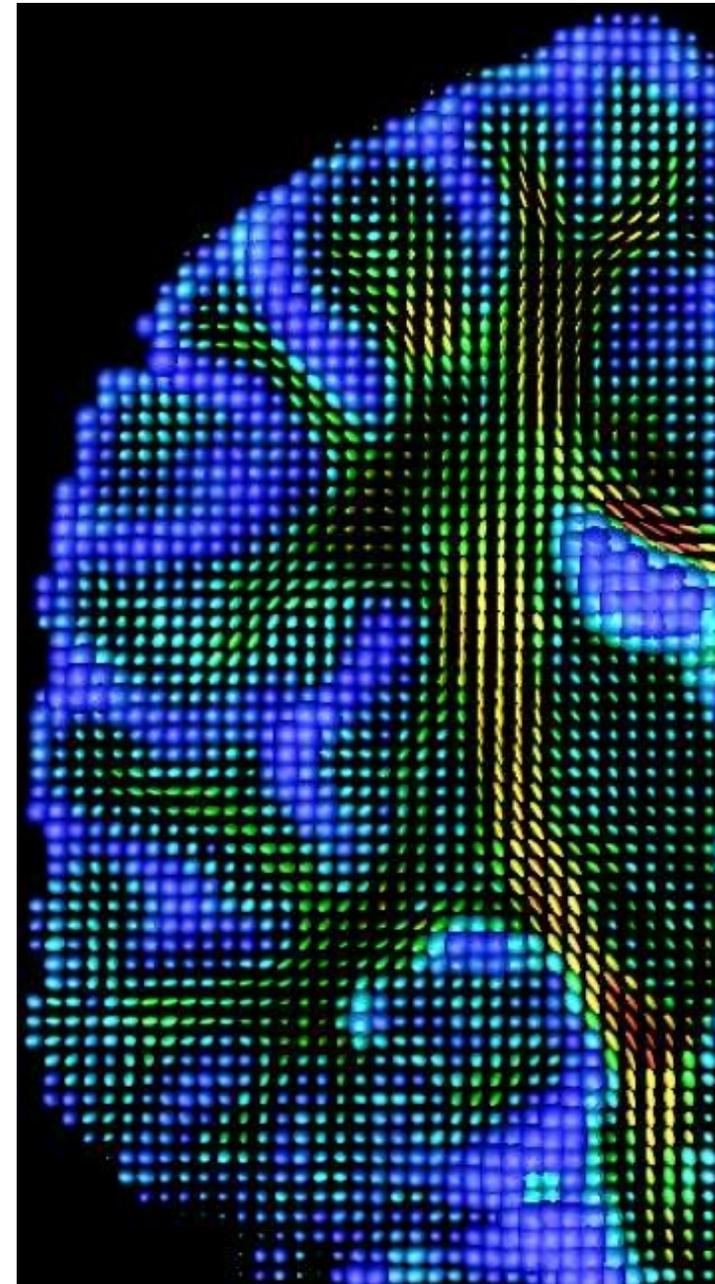
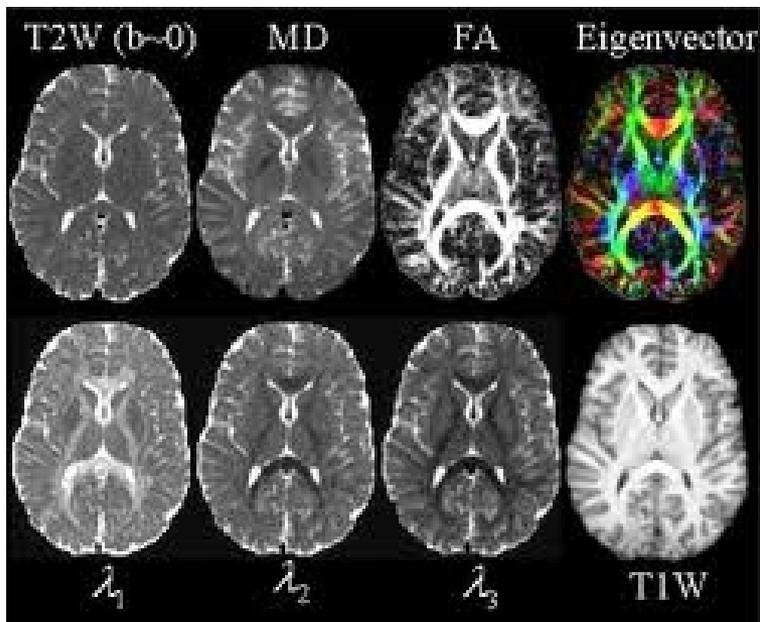


Anisotropie (FA) $\sqrt{\frac{3}{2}} \sqrt{\frac{(\lambda_1 - \bar{\lambda})^2 + (\lambda_2 - \bar{\lambda})^2 + (\lambda_3 - \bar{\lambda})^2}{\lambda_1^2 + \lambda_2^2 + \lambda_3^2}}$

Diffusion moyenne (MD) $\bar{\lambda}$

Diffusivité axiale (AD) λ_1

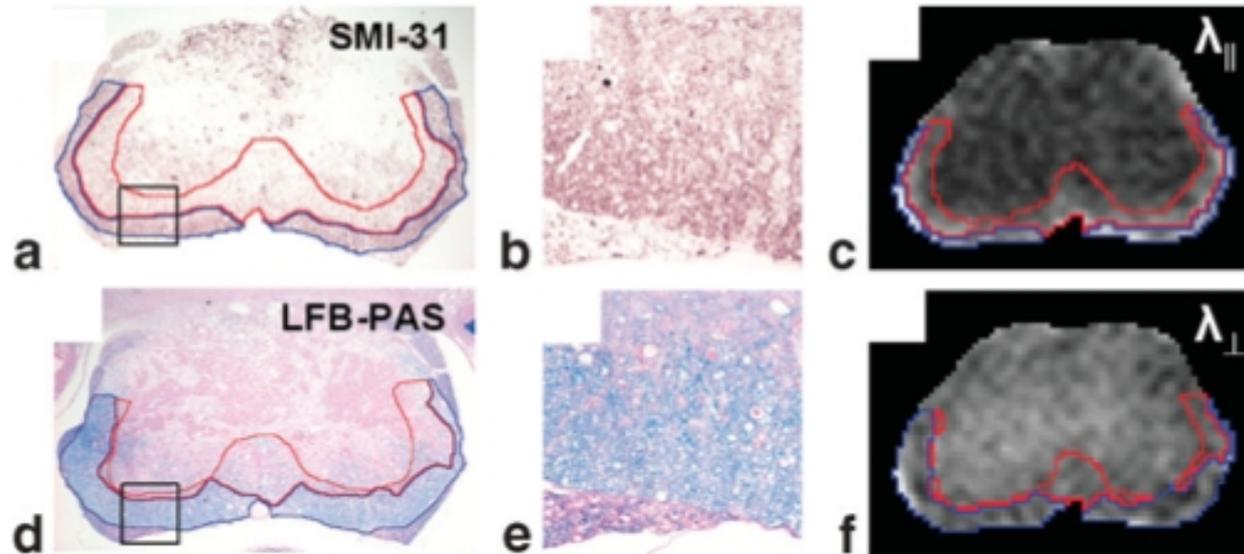
Diffusivité radiale (RD) $(\lambda_2 + \lambda_3)/2$



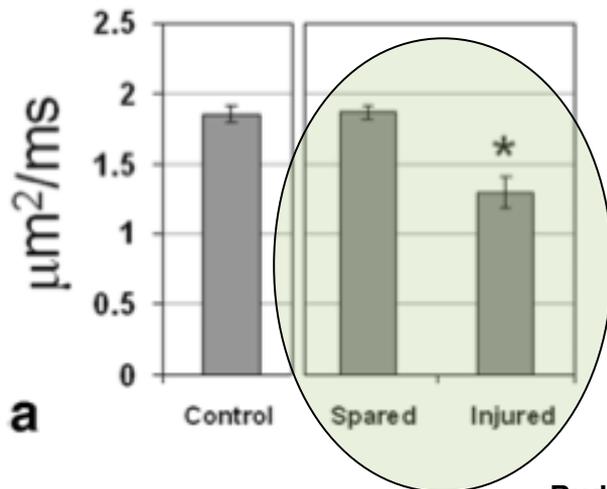
Biomarqueurs d'intégrité

Traumatisme médullaire: pathologie axonale

FIG. 2. SCI segmentation and registration. Histological sections stained for intact axons with SMI-31 (a) and for myelin with LFB (d). Panels b and e are magnified views of the boxed regions in a and d, respectively. The outlines reflect the injured (red) and spared (blue) WM regions that were manually segmented on each of the digitized histological sections and registered to the DTI parameter maps of λ_{\parallel} (c) and λ_{\perp} (f).



Diffusivité axiale



Diffusivité radiale

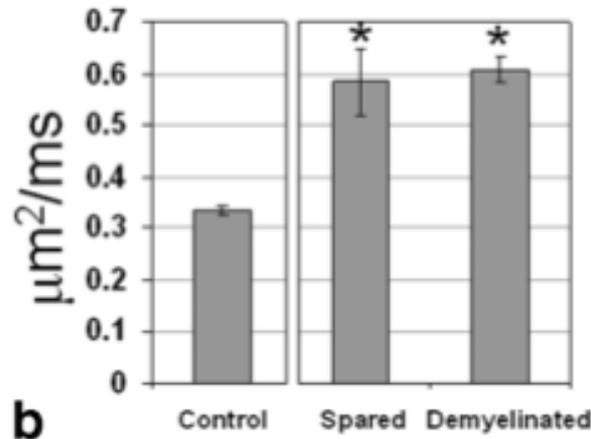


FIG. 4. SCI-ROI analysis. a: Segmented and registered ROIs from the SMI-31-stained sections were used to compare λ_{\parallel} from the injured and spared WM of mice with SCI in comparison with values from the WM of control mice. b: The λ_{\perp} obtained from ROIs of the LFB-stained sections from the demyelinated and spared WM of mice with SCI were compared with control values. Values represent the mean values from four mice with SCI and three control mice. Error bars indicate the SEM. * $P < 0.05$ compared to controls.

Sclérose en plaques: pathologie myélinique

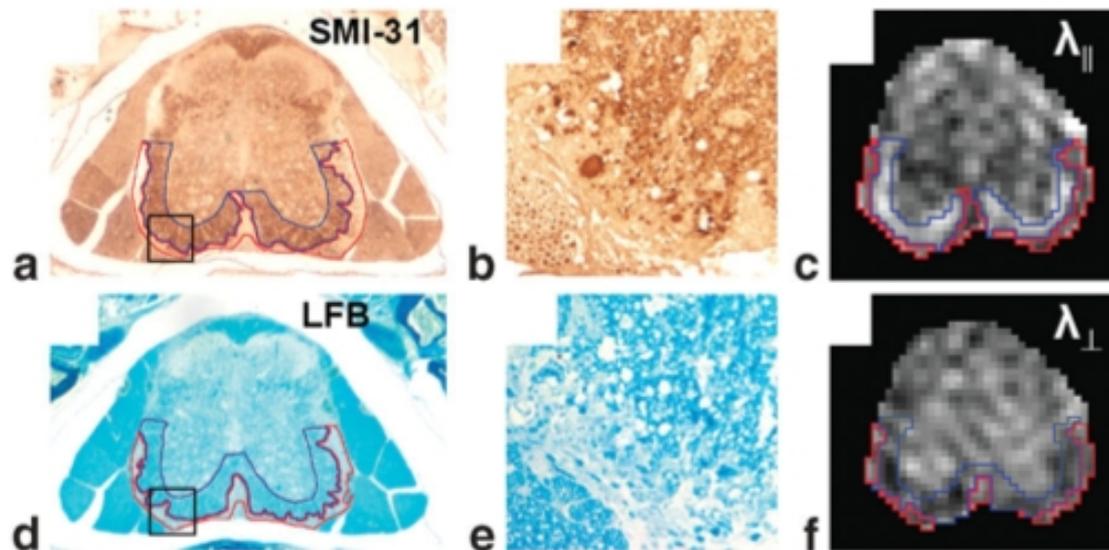


FIG. 5. EAE segmentation and registration. Histological sections were stained for intact axons with SMI-31 (a) and for myelin with LFB (d). Panels b and e are magnified views of the boxed regions in a and d, respectively. The outlines reflect the injured (red) and spared (blue) WM regions that were manually segmented on each of the digitized histological sections and registered to the DTI parameter maps of λ_{\parallel} (c) and λ_{\perp} (f). [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

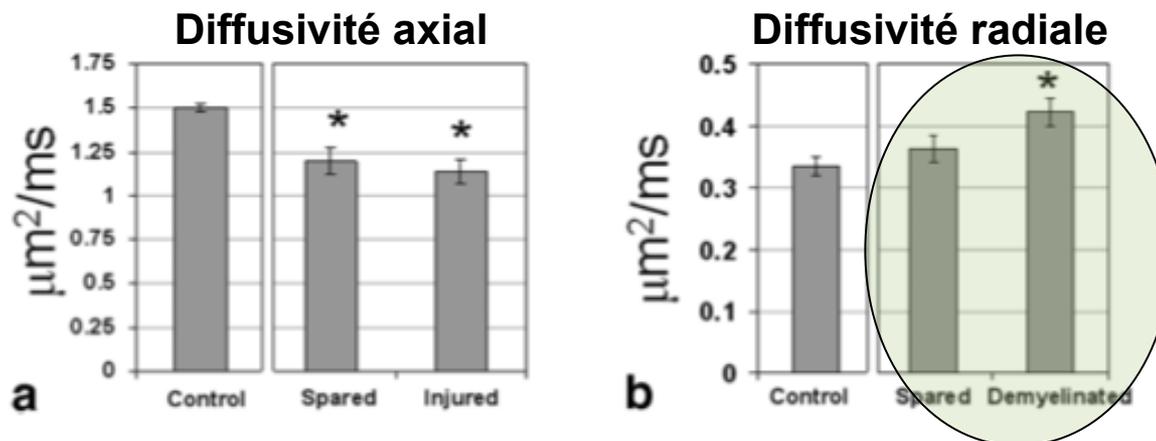


FIG. 7. EAE-ROI analysis. **a:** Segmented and registered ROIs from the SMI-31-stained sections were used to compare the λ_{\parallel} from the injured and spared WM of mice with EAE in comparison with the values from the WM of control mice. **b:** ROIs from the LFB-stained sections were used to compare the λ_{\perp} from the demyelinated and spared WM of mice with EAE in comparison with control values. Values represent the mean values from five mice with EAE and five control mice. Error bars indicate the SEM. * $P < 0.05$ compared to controls.

Procédure

- *Promoteur l'IRME*
- *Evaluation clinique, neuropsychologique, et imagerie*
- *Longitudinale (phase aiguë et chronique)*
- *Etude 1: 23 patients TCL et 23 volontaires sains*
- *Etude 2: 72 patients TCL et 42 témoins*

■ Neuropsychologie et clinique

- **Evaluation par une psychologue**
 - *Sophie Caplain*
- **Quantifie les troubles des domaines**
 - *Cognitif* (TMTB, Stroop, Baddeley...)
 - *Emotionnel* (HAD, qualité de vie)
 - *Somatique* (EVA)
- **Pronostic fonctionnel évalué en chronique**
 - *Absence/présence de SPC*
 - *Questionnaire de plaintes*

■ Imagerie multimodale

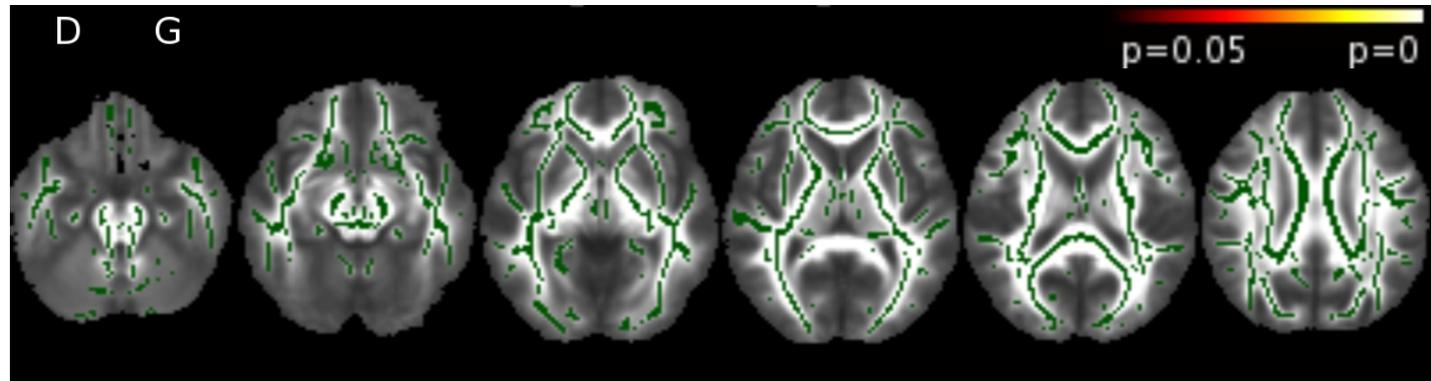
- **Structurale: T1, T2, FLAIR, SWI**
 - *Détection des lésions apparentes, hémorragies, hématomes, etc*
- **Microstructurelle: DTI**
 - *Lésions axonales (intégrité)*
- **Fonctionnelle: tâche de n-back et repos**
 - *Répercussions sur la fonction*

Association des lésions axonales diffuses aux déficits comportementaux: *Etude 1*

Tract-Based Spatial Statistics – TBSS

diffusivité moyenne

PCS- vs. C

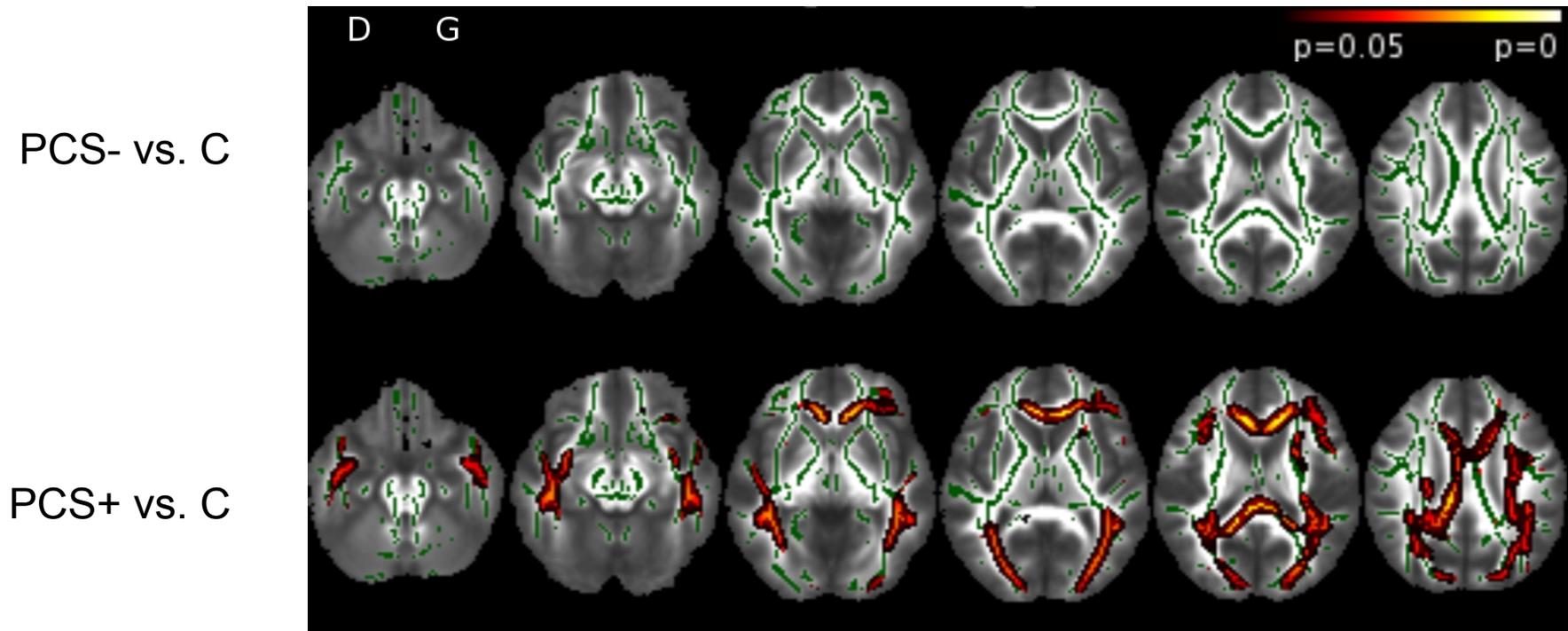


$p < 0,05$ corrigé

Association des lésions axonales diffuses aux déficits comportementaux: *Etude 1*

Tract-Based Spatial Statistics – TBSS

diffusivité moyenne

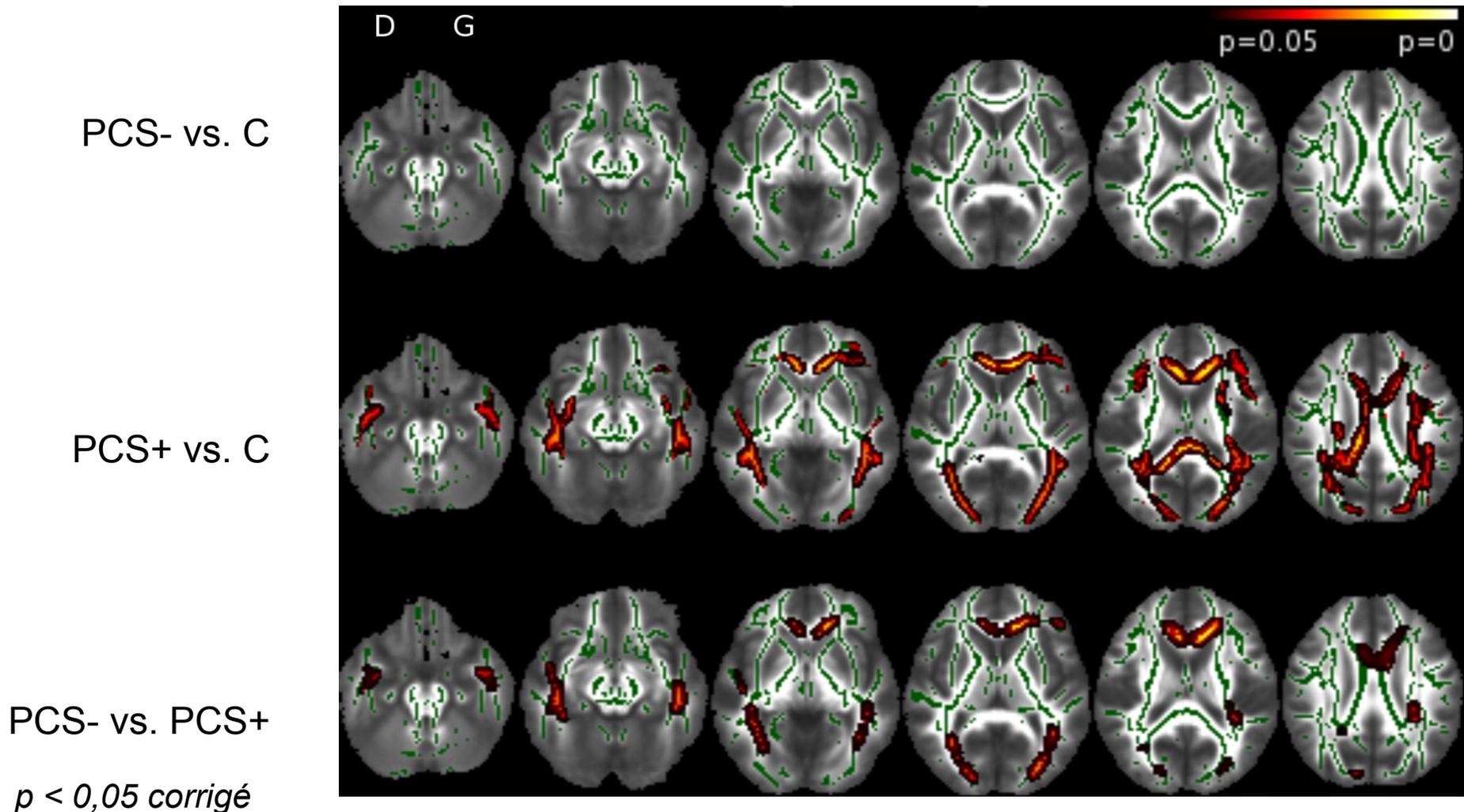


$p < 0,05$ corrigé

Association des lésions axonales diffuses aux déficits comportementaux: *Etude 1*

Tract-Based Spatial Statistics – TBSS

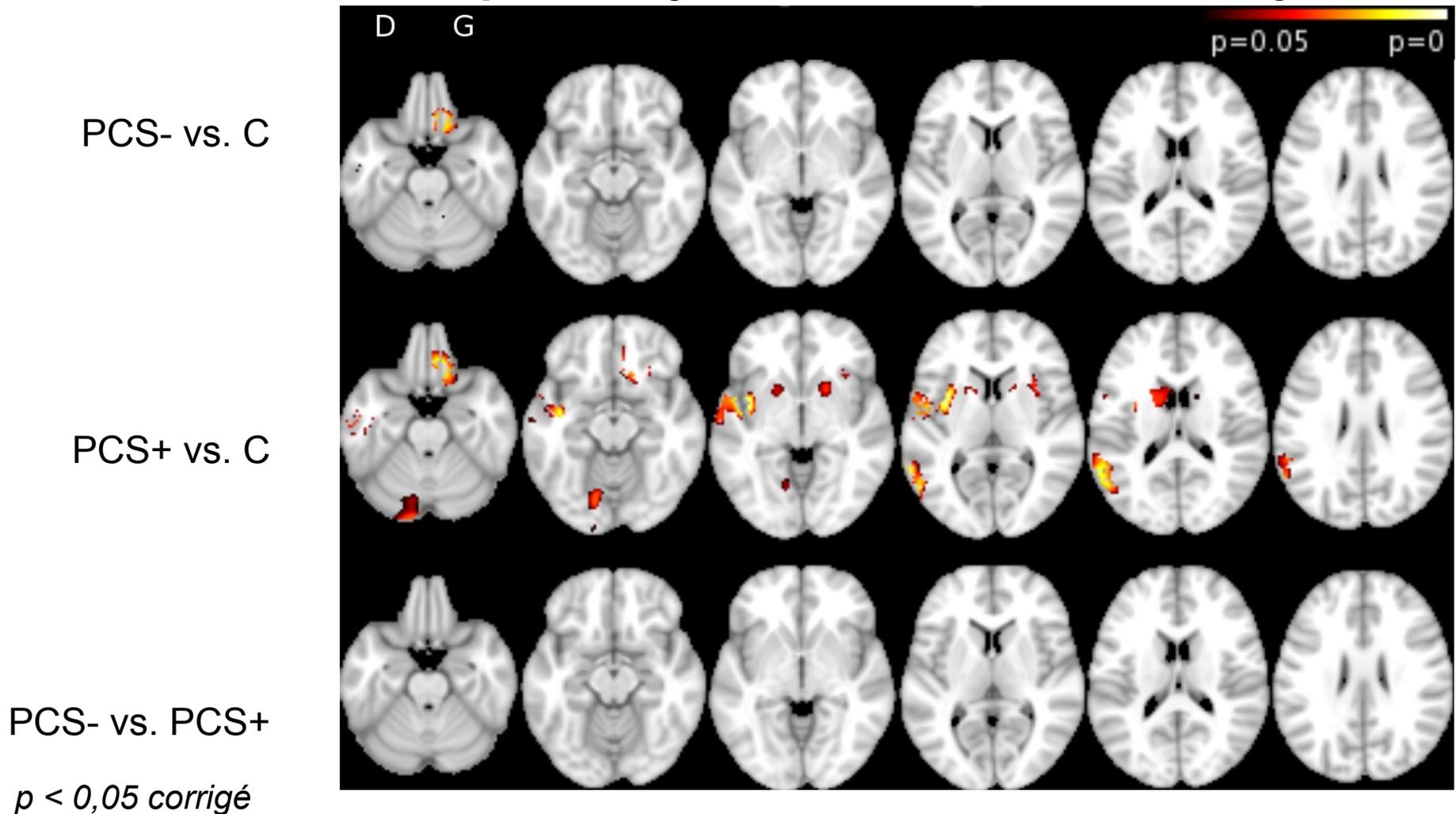
diffusivité moyenne



Etude 1

Voxel-Based Morphometry – VBM

matière grise

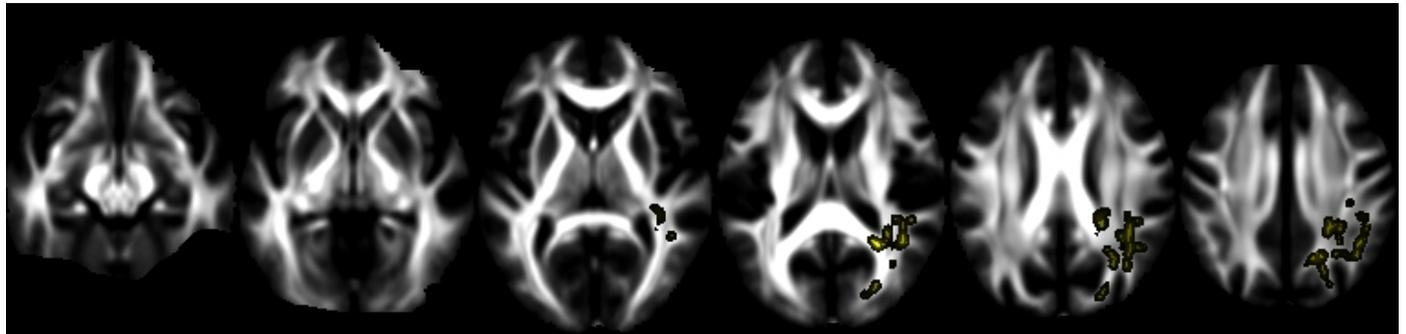


Association des lésions axonales diffuses aux déficits comportementaux: *Etude 2*

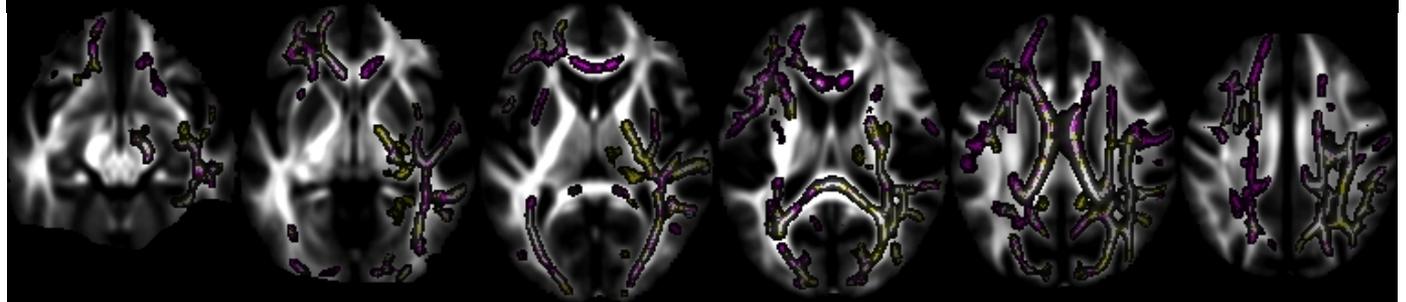
Tract-Based Spatial Statistics – TBSS

diffusivité moyenne

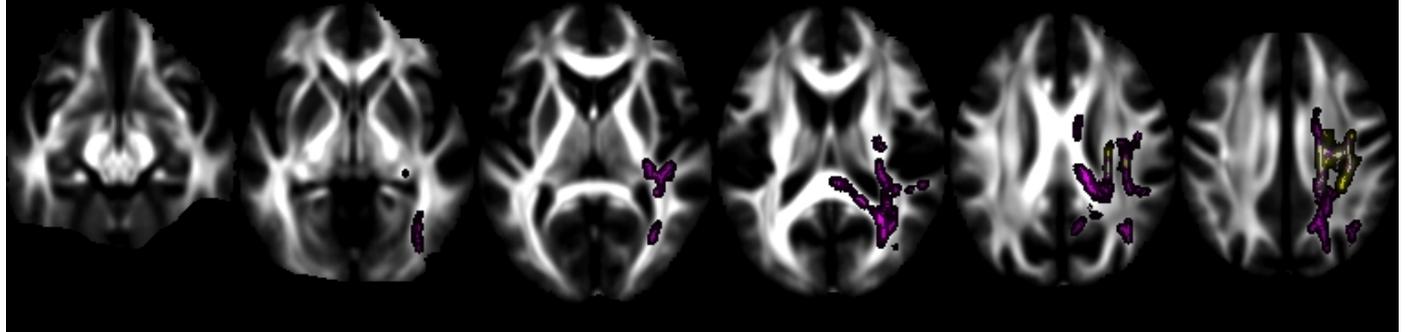
PCS- vs. C



PCS+ vs. C



PCS- vs. PCS+



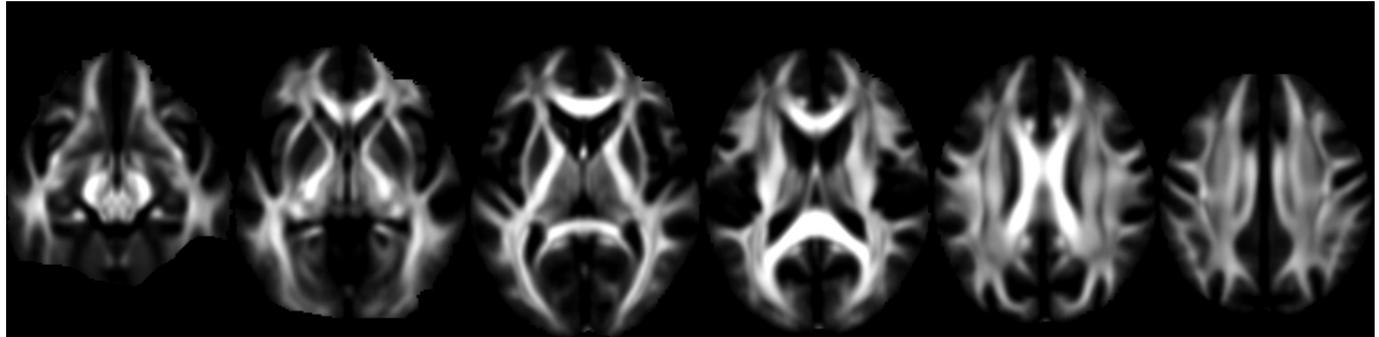
$p < 0,05$ corrigé

Association des lésions axonales diffuses aux déficits comportementaux: *Etude 2*

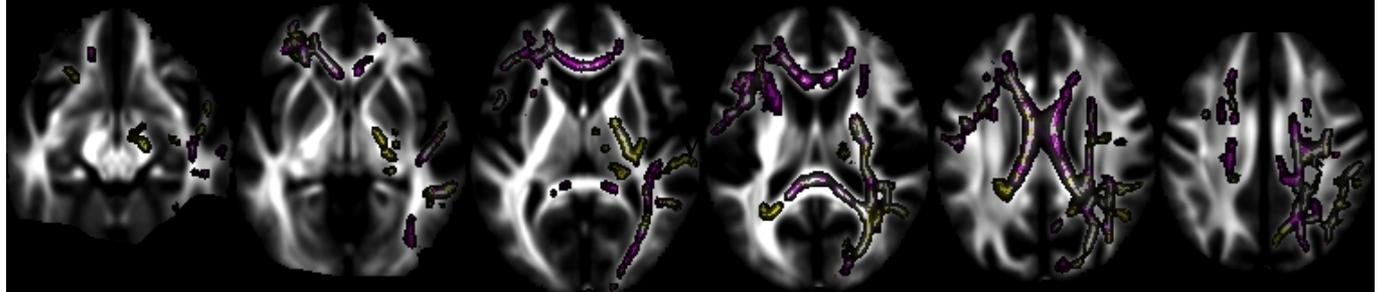
Tract-Based Spatial Statistics – TBSS

diffusivité axiale

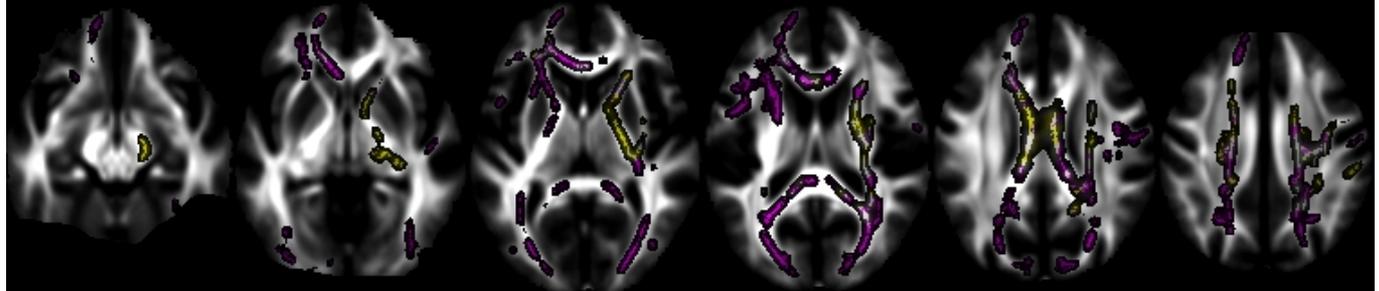
PCS- vs. C



PCS+ vs. C

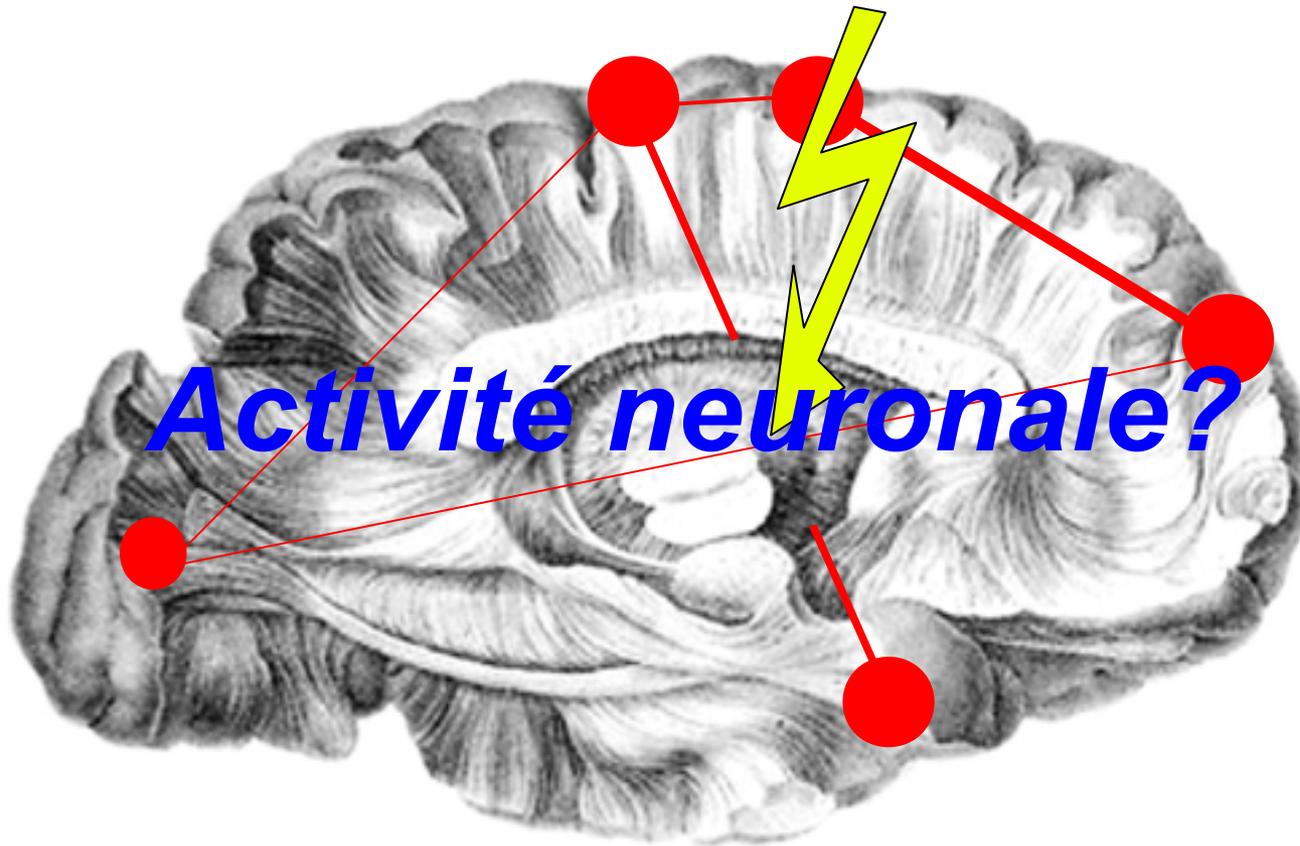


PCS- vs. PCS+

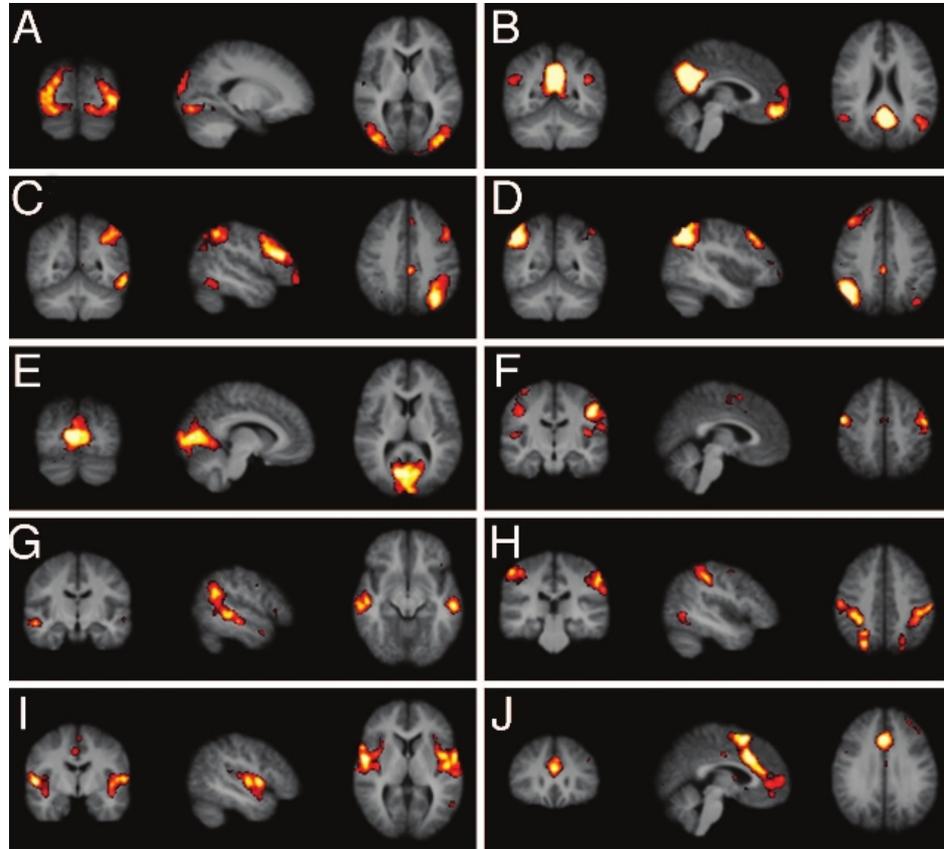
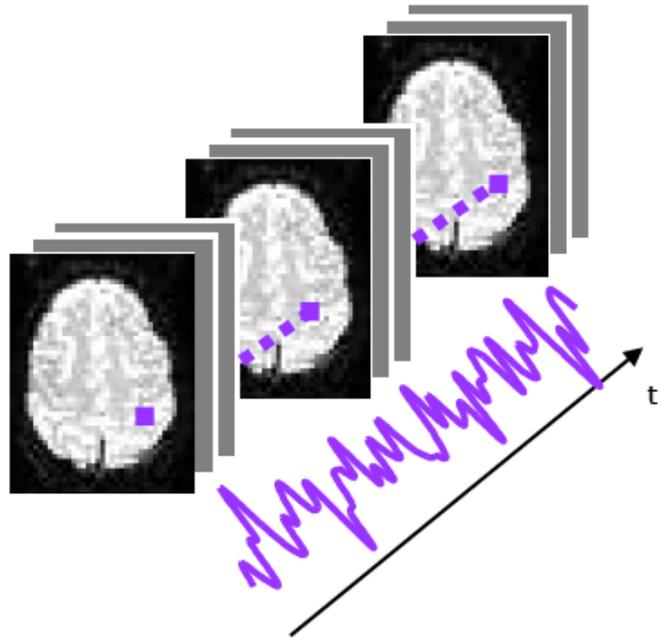


$p < 0,05$ corrigé

Structure de la matière blanche

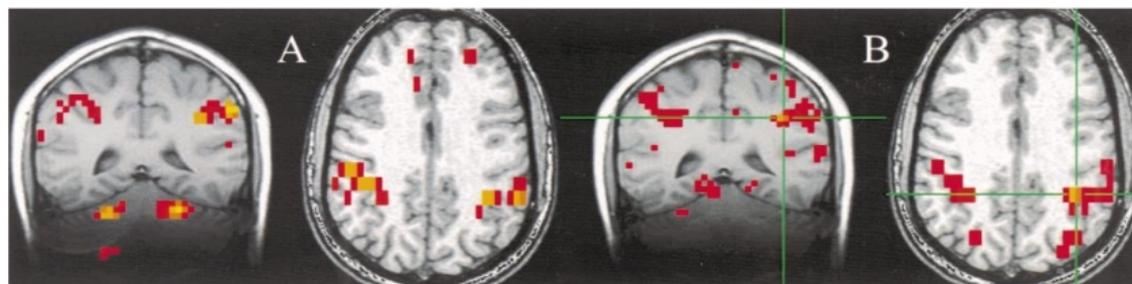


Etat de repos



Paradigme

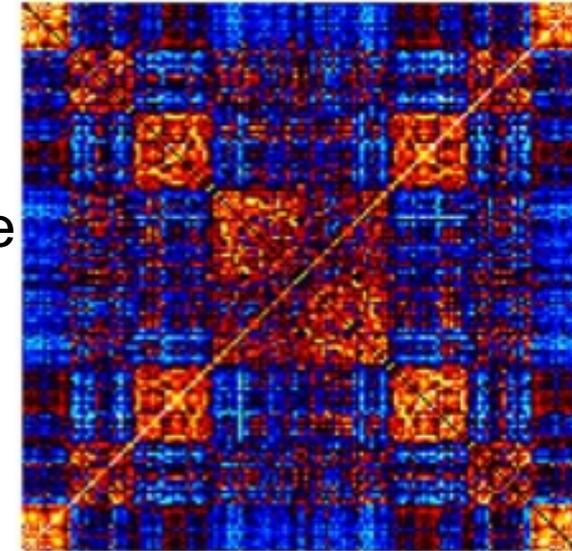
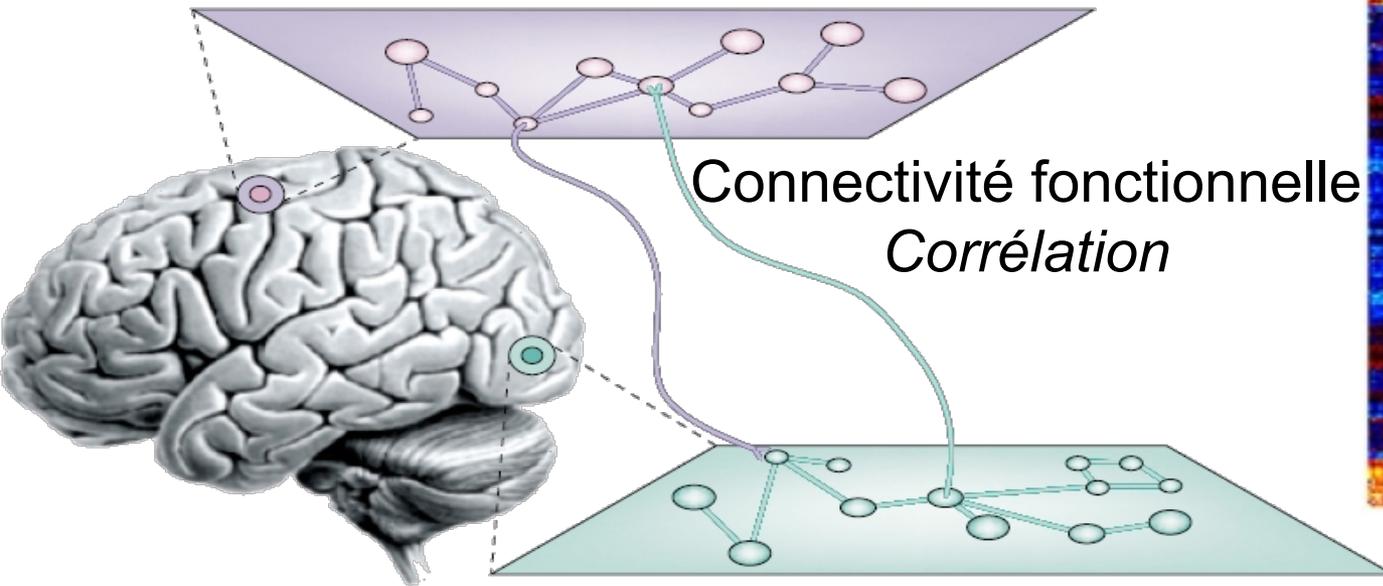
Damoiseaux et al., *PNAS* (2006)



Cordes et al., *AJNR* (2000)

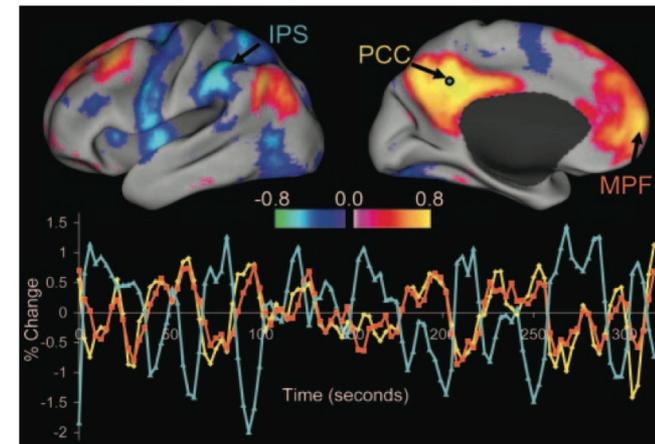
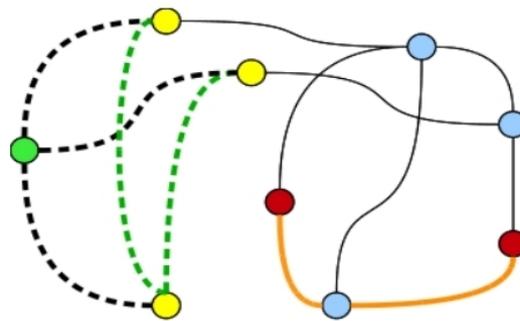
Réseau cérébral

Ensemble de régions distribuées dans le cerveau interagissant entre-elles, afin de réaliser une tâche

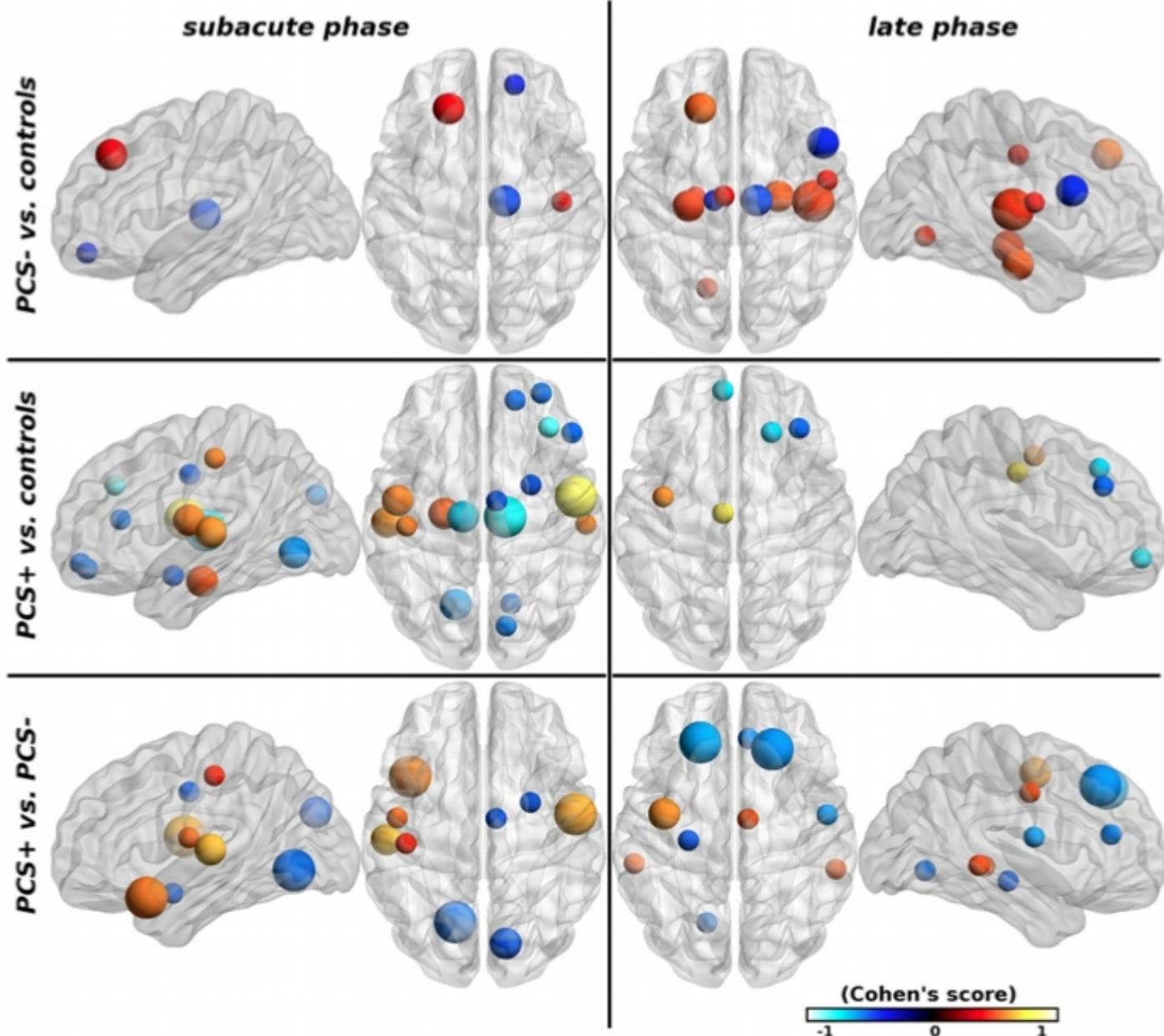


Théorie des graphes

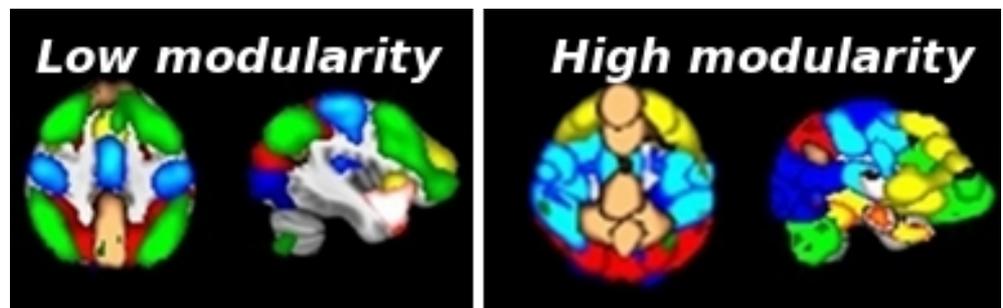
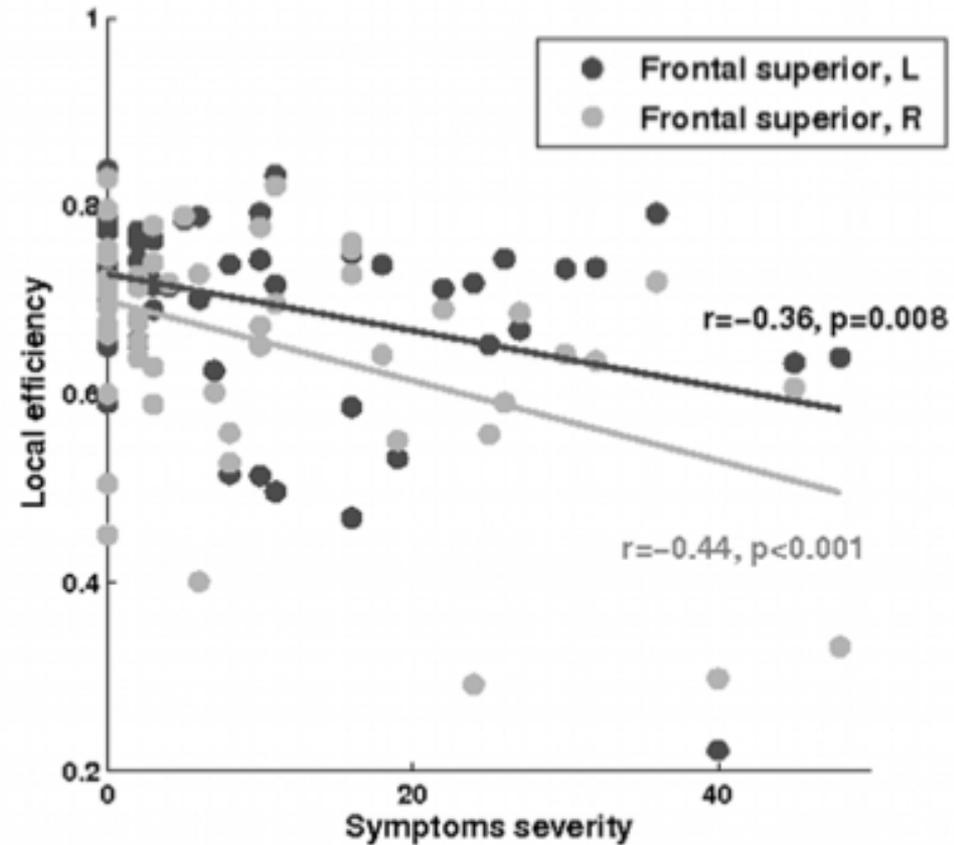
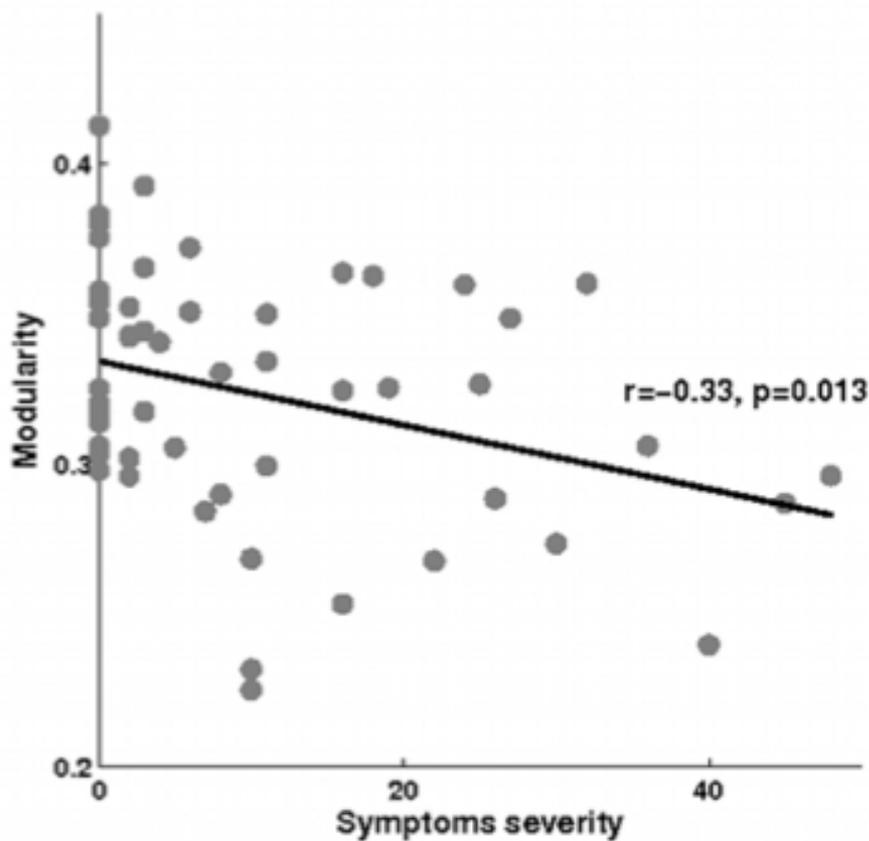
- Degré
- Efficacité
- Centralité
- Modularité
- ...



Association de changement topographique aux déficits comportementaux: *Etude 2*



Association de changement topographique aux déficits comportementaux: *Etude 2*



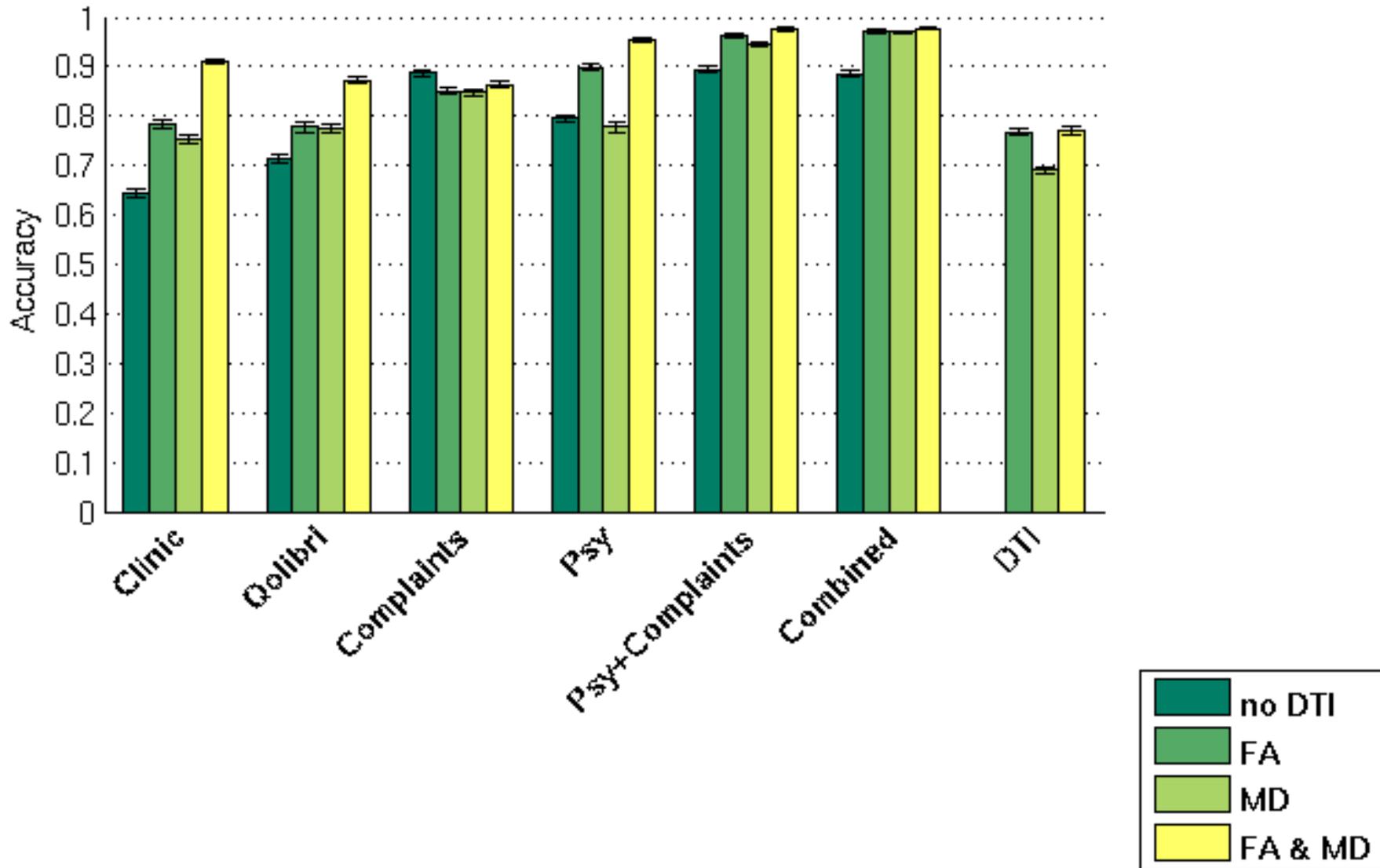
Prédiction multifactorielle et multicentrique des déficits comportementaux

Lieu repassement	Sexes	NCS	Age	Emosan entré	Emosan envoyé	Emosan total	TMT A	TMT B	B-A	Sés L/C	Stroop M	Stroop C	Stroop M/C	Interférences	PASAT BR	PASAT Emia	PASAT Emal	PASSAT NR	Fluence Animaux	Fluence M	GZ	QZ	F(Std)	F%	TT BAS NV	T HAUT NV	Col	Sés A
P001DAC	F	5.00	21.00	5.00	5.00	9.00	18.00	40.00	22.00	8.00	47.00	60.00	75.00	11.00	60.00	0.00	0.00	20.00	20.00	20.00	18.00	18.00	2.56	5.00	8.00	8.00	52.00	
P002ALB	M	2.00	19.00	5.00	3.00	4.00	28.00	148.00	120.00	4.00	42.00	42.00	53.00	59.00	41.00	0.00	3.00	16.00	18.00	5.00	290.00	14.00	4.82	5.00	4.00	7.00	34.00	
P003BAT	M	3.00	28.00	8.00	4.00	4.00	24.00	53.00	29.00	9.00	52.00	54.00	69.00	65.00	59.00	0.00	0.00	1.00	22.00	11.00	595.00	5.00	0.84	5.00	8.00	5.00	33.00	
P004LAN	M	3.00	40.00	8.00	4.00	9.00	45.00	111.00	66.00	10.00	35.00	36.00	36.00	46.00	48.00	2.00	2.00	7.00	8.00	498.00	33.00	8.12	3.00	7.00	2.50	48.00		
P007LON	F	1.00	36.00	6.00	5.00	10.00	25.00	73.00	48.00	8.00	41.00	52.00	41.00	41.00	39.00	0.00	10.00	11.00	10.00	7.00	362.00	20.00	5.52	4.00	7.00	6.00	33.00	
P007LOP	M	2.00	31.00	4.00	3.00	7.00	36.00	138.00	102.00	4.00	NaN	NaN	NaN	25.00	5.00	12.00	16.00	13.00	NaN	306.00	13.00	4.24	1.00	1.00	1.00	6.00	NaN	
P008AAM	F	3.00	29.00	4.00	5.00	4.00	29.00	97.00	77.00	7.00	44.00	54.00	68.00	67.00	52.00	0.00	1.00	17.00	6.00	572.00	19.00	3.32	4.00	8.00	7.00	42.00		
P018THV	M	4.00	30.00	7.00	6.00	11.00	15.00	32.00	17.00	11.00	60.00	64.00	82.00	72.00	59.00	1.00	0.00	0.00	32.00	19.00	520.00	10.00	1.92	5.00	8.00	7.00	21.00	
P019ZAP	F	4.00	30.00	5.00	5.00	7.00	17.00	32.00	15.00	5.00	49.00	47.00	57.00	62.00	56.00	0.00	1.00	3.00	14.00	9.00	589.00	5.00	0.84	5.00	8.00	8.00	56.00	
P020BOP	M	2.00	41.00	5.00	4.00	7.00	30.00	90.00	60.00	8.00	54.00	54.00	56.00	54.00	56.00	0.00	15.00	3.00	326.00	28.00	6.58	5.00	6.00	3.00	33.00			
P021MYC	F	2.00	47.00	6.00	2.00	3.00	62.00	168.00	104.00	6.00	45.00	42.00	26.00	29.00	NaN	NaN	NaN	12.00	1.00	304.00	36.00	11.84	4.00	2.00	8.00	37.00		
P022CHN	M	3.00	29.00	5.00	4.00	4.00	17.00	55.00	38.00	9.00	48.00	50.00	41.00	44.00	47.00	3.00	7.00	20.00	11.00	369.00	19.00	5.14	5.00	7.00	7.00	36.00		
P023RHS	M	5.00	42.00	6.00	4.00	9.00	35.00	95.00	60.00	9.00	54.00	50.00	43.00	41.00	60.00	0.00	0.00	23.00	15.00	322.00	40.00	11.38	5.00	6.00	6.00	66.00		
P024FRT	M	5.00	31.00	6.00	6.00	9.00	24.00	33.00	9.00	6.00	48.00	50.00	47.00	47.00	57.00	0.00	1.00	2.00	29.00	11.00	491.00	10.00	2.03	5.00	8.00	7.5	21.00	
P025TRF	M	4.00	30.00	5.00	5.00	7.00	23.00	69.00	46.00	8.00	41.00	46.00	44.00	49.00	51.00	0.00	2.00	7.00	15.00	10.00	496.00	7.00	1.40	5.00	7.00	5.00	42.00	
P026CAS	M	3.00	30.00	6.00	6.00	7.00	23.00	56.00	38.00	9.00	46.00	50.00	62.00	62.00	56.00	3.00	1.00	0.00	NaN	NaN	476.00	40.00	8.61	4.00	7.00	5.00	43.00	
P027KNS	M	4.00	38.00	5.00	4.00	5.00	29.00	88.00	59.00	8.00	54.00	54.00	71.00	76.00	69.00	0.00	6.00	0.00	26.00	6.00	633.00	12.00	3.78	5.00	8.00	7.00	28.00	
P028OBB	M	4.00	54.00	6.00	6.00	7.00	38.00	104.00	64.00	8.00	48.00	46.00	50.00	51.00	2.00	2.00	5.00	19.00	14.00	480.00	42.00	8.75	4.00	7.00	4.00	45.00		
P029JEC	M	3.00	47.00	5.00	3.00	3.00	38.00	104.00	64.00	8.00	42.00	46.00	54.00	56.00	3.00	1.00	0.00	16.00	3.00	440.00	33.00	7.50	4.00	4.00	8.00	39.00		
P030CZS	F	2.00	40.00	4.00	3.00	3.00	30.00	82.00	57.00	7.00	44.00	40.00	34.00	43.00	43.00	8.00	7.00	4.00	22.00	15.00	419.00	23.00	5.48	2.00	5.00	4.00	51.00	
P031FEA	M	5.00	20.00	5.00	5.00	1.00	20.00	42.00	22.00	0.00	89.00	52.00	54.00	53.00	60.00	0.00	0.00	0.00	16.00	0.00	644.00	22.00	3.41	5.00	4.00	8.00	5.00	37.00
P032LAB	F	5.00	38.00	6.00	5.00	9.00	33.00	72.00	39.00	6.00	40.00	42.00	44.00	50.00	56.00	0.00	1.00	3.00	21.00	11.00	525.00	5.00	0.95	4.00	9.00	9.00	26.00	
P033LEK	M	4.00	29.00	7.00	8.00	10.00	49.00	82.00	42.00	9.00	47.00	52.00	59.00	58.00	45.00	0.00	2.00	17.00	13.00	551.00	11.00	1.99	5.00	8.00	7.00	33.00		
P034MAA	M	3.00	48.00	7.00	6.00	8.00	11.00	49.00	65.00	10.00	47.00	47.00	44.00	44.00	45.00	2.00	4.00	9.00	20.00	13.00	337.00	20.00	5.93	5.00	7.00	2.00	50.00	
P035SET	M	4.00	43.00	4.00	3.00	3.00	38.00	104.00	64.00	8.00	42.00	42.00	44.00	50.00	56.00	0.00	1.00	3.00	21.00	11.00	525.00	5.00	0.95	4.00	9.00	9.00	26.00	
P036BIR	M	3.00	49.00	8.00	7.00	9.00	11.00	49.00	65.00	10.00	47.00	47.00	44.00	44.00	45.00	2.00	4.00	9.00	20.00	13.00	337.00	20.00	5.93	5.00	7.00	2.00	50.00	
P038KHK	M	3.00	18.00	7.00	6.00	8.00	11.00	21.00	19.00	9.00	42.00	42.00	44.00	50.00	56.00	0.00	1.00	3.00	17.00	7.00	274.00	8.00	2.18	3.00	4.00	2.00	67.00	
P039CAX	M	5.00	38.00	7.00	7.00	12.00	16.00	35.00	19.00	9.00	57.00	60.00	68.00	59.00	60.00	0.00	0.00	0.00	29.00	18.00	596.00	18.00	3.02	5.00	8.00	9.00	31.00	
P040ZAZ	M	4.00	20.00	5.00	5.00	1.00	29.00	133.00	104.00	6.00	40.00	41.00	36.00	34.00	55.00	0.00	4.00	1.00	21.00	10.00	444.00	28.00	6.30	4.00	6.00	8.00	38.00	
P042MAT	M	5.00	33.00	7.00	10.00	8.00	29.00	41.00	15.00	8.00	48.00	44.00	49.00	51.00	56.00	1.00	2.00	1.00	23.00	13.00	421.00	3.00	0.71	5.00	8.00	8.00	40.00	
P043BOH	F	4.00	28.00	6.00	6.00	7.00	28.00	74.00	46.00	10.00	41.00	34.00	50.00	60.00	48.00	1.00	8.00	2.00	NaN	NaN	440.00	0.00	NaN	NaN	440.00			
P044THA	F	5.00	23.00	7.00	6.00	8.00	21.00	66.00	45.00	8.00	29.00	38.00	38.00	51.00	45.00	1.00	8.00	23.00	10.00	550.00	15.00	2.50	5.00	8.00	8.00	29.00		
P045CHE	F	5.00	29.00	4.00	5.00	6.00	29.00	116.00	91.00	9.00	28.00	38.00	34.00	49.00	1.00	16.00	17.00	8.00	291.00	17.00	8.60	291.00	17.00	8.60	291.00			
P047SAS	M	1.00	29.00	5.00	3.00	2.00	20.00	102.00	52.00	4.00	44.00	40.00	33.00	33.00	43.00	6.00	5.00	6.00	16.00	7.00	405.00	23.00	3.00	4.00	7.00	55.00		
P048CHF	F	2.00	47.00	5.00	3.00	3.00	6.00	33.00	162.00	129.00	6.00	44.00	42.00	38.00	NaN	NaN	NaN	28.00	12.00	466.00	25.00	4.66	5.00	8.00	8.00	56.00		
P049AWY	M	5.00	58.00	5.00	3.00	7.00	61.00	189.00	128.00	6.00	39.00	36.00	44.00	54.00	38.00	0.00	10.00	12.00	NaN	NaN	482.00	15.00	2.50	5.00	8.00	8.00	56.00	
P050KRM	M	1.00	20.00	6.00	6.00	10.00	10.00	25.00	60.00	35.00	8.00	42.00	56.00	42.00	40.00	45.00	0.00	6.00	9.00	26.00	12.00	422.00	17.00	1.00	5.00	8.00	8.00	56.00
P053BLE	M	5.00	23.00	6.00	6.00	6.00	13.00	44.00	8.00	11.00	42.00	44.00	45.00	50.00	59.00	1.00	0.00	0.00	27.00	17.00	491.00	5.00	0.84	5.00	8.00	8.00	56.00	
P055BET	M	5.00	23.00	8.00	6.00	6.00	13.00	44.00	49.00	16.00	44.00	49.00	46.00	48.00	57.00	2.00	1.00	0.00	22.00	15.00	450.00	14.00	3.50	5.00	8.00	8.00	56.00	
P056LAR	F	5.00	36.00	5.00	4.00	4.00	36.00	104.00	64.00	8.00	45.00	46.00	57.00	NaN	57.00	0.00	0.00	3.00	40.00	17.00	554.00	31.00	5.59	5.00	6.00	4.00	55.00	
P057VIE	M	5.00	34.00	8.00	6.00	6.00	22.00	44.00	07.00	23.00	11.00	50.00	42.00	47.00	50.00	58.00	0.00	0.00	2.00	26.00	8.00	618.00	0.00	NaN	NaN	482.00		
P058BIN	M	2.00	40.00	3.00	3.00	1.00	43.00	101.00	35.00	NaN	34.00	25.00	38.00	45.00	23.00	8.00	8.00	21.00	NaN	NaN	468.00	0.00	NaN	NaN	468.00			
P059BOH	M	3.00	37.00	6.00	7.00	11.00	45.00	80.00	35.00	8.00	54.00	56.00	41.00	36.00	50.00	3.00	4.00	3.00	25.00	11.00	443.00	0.00	NaN	NaN	443.00			
P060TAA	M	5.00	63.00	6.00	4.00	9.00	28.00	74.00	46.00	10.00	41.00	34.00	50.00	60.00	48.00	1.00	8.00	2.00	NaN	NaN	440.00	0.00	NaN	NaN	440.00			
P063PLP	M	4.00	37.00	5.00	3.00	4.00	21.00	66.00	45.00	8.00	29.00	38.00	38.00	51.00	45.00	1.00	8.00	23.00	10.00	550.00	15.00	2.50	5.00	8.00	8.00	56.00		
P064DUB	M	3.00	47.00	6.00	4.00	9.00	37.00	95.00	58.00	8.00	50.00	52.00	52.00	50.00	53.00	3.00	4.00	0.00	28.00									

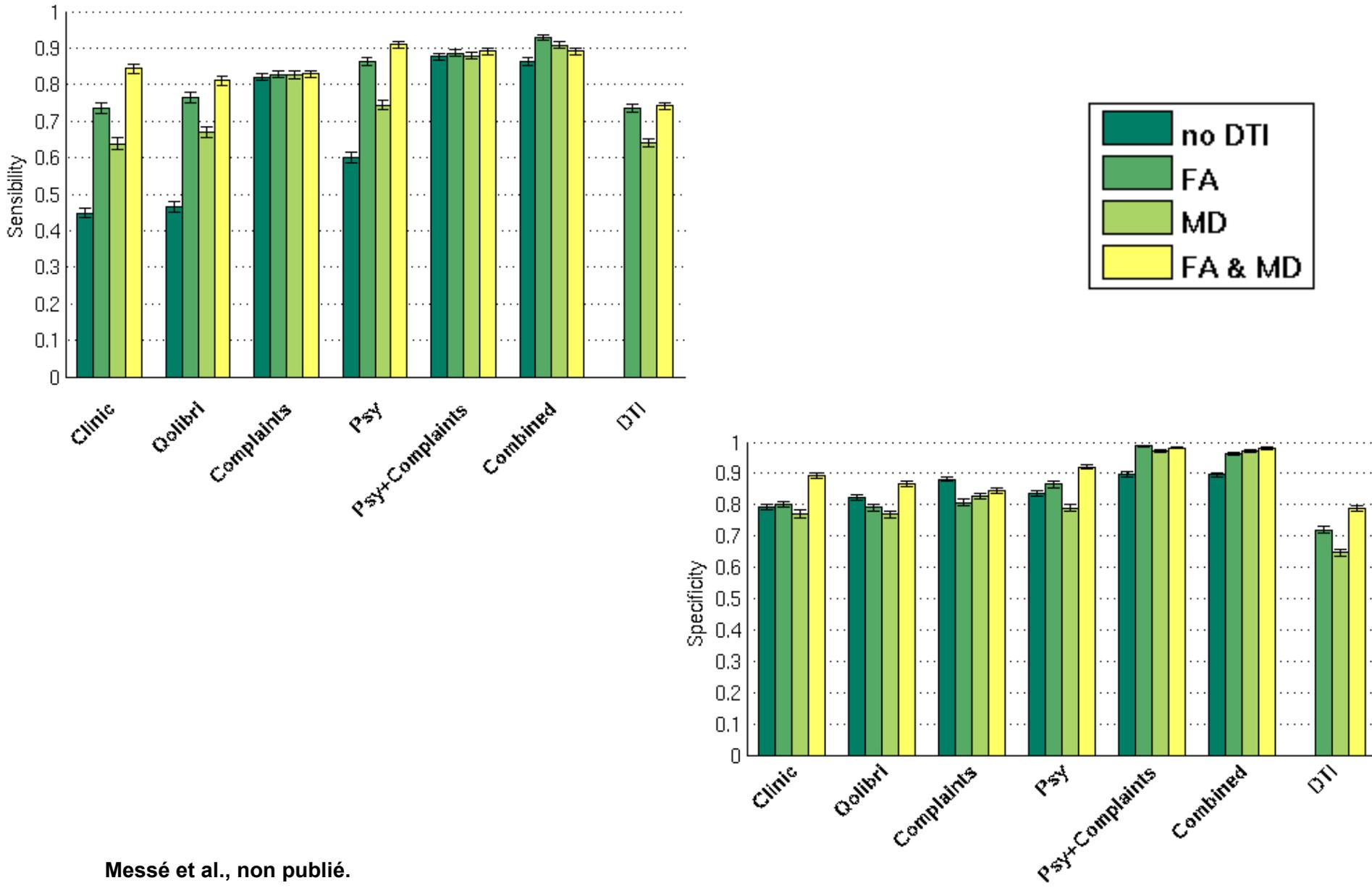
Prédiction multifactorielle et multicentrique des déficits comportementaux

Lieu recrutement	Sexe	NCS	Age	Essai en ordre	Essai en aveugle	Essai en total	TMT A	TMT B	B-A	Sés L/C	Stroop M	Stroop C	Stroop M/C	Interférence	PASAT NR	PR PASAT	EMM PASAT	PRAT Eval	PASSAT NR	Fluence Animaux	Fluence M	G2	Flo(40)	F% 100	TT BAS NIV	T HAUT NIV	Oct	ShA	
PRODACC	F	5.00	21.00	8.00	9.00	9.00	14.00	28.00	8.00	47.00	60.00	73.00	71.00	60.00	16.00	16.00	16.00	16.00	16.00	18.00	5.00	280.00	14.00	4.82	5.00	4.00	7.00	34.00	
PROGALLE	F	2.00	18.00	5.00	3.00	4.00	28.00	148.00	120.00	4.00	42.00	42.00	53.00	59.00	41.00	16.00	16.00	16.00	16.00	11.00	3.00	350.00	15.00	5.24	4.00	8.00	1.00	52.00	
PROGASAT	F	3.00	28.00	8.00	4.00	4.00	24.00	23.00	38.00	9.00	52.00	54.00	69.00	86.00	59.00	16.00	16.00	16.00	16.00	11.00	3.00	350.00	15.00	5.24	4.00	8.00	1.00	52.00	
PROGALAN	M	3.00	48.00	8.00	4.00	8.00	45.00	111.00	66.00	10.00	38.00	38.00	36.00	46.00	49.00	16.00	16.00	16.00	16.00	22.00	6.00	400.00	33.00	8.12	3.00	7.00	2.50	48.00	
PROGALAN	F	1.00	38.00	8.00	5.00	10.00	28.00	19.00	38.00	4.00	41.00	52.00	41.00	52.00	41.00	16.00	16.00	16.00	16.00	11.00	3.00	350.00	15.00	5.24	4.00	8.00	1.00	52.00	
PROGLOP	M	2.00	31.00	4.00	4.00	3.00	36.00	138.00	102.00	8.00	NaN	NaN	NaN	NaN	25.00	16.00	16.00	16.00	13.00	3.00	300.00	13.00	4.24	1.00	1.00	6.00	NaN	NaN	
PROGASAM	F	4.00	25.00	4.00	5.00	4.00	25.00	37.00	77.00	7.00	64.00	54.00	68.00	67.00	68.00	16.00	16.00	16.00	16.00	17.00	8.00	372.00	15.00	3.50	4.00	8.00	7.00	40.00	
PROGATHAV	M	4.00	38.00	7.00	6.00	11.00	15.00	32.00	17.00	11.00	60.00	64.00	82.00	72.00	59.00	16.00	16.00	16.00	16.00	3.00	14.00	9.00	560.00	3.00	0.84	5.00	8.00	56.00	
PROGATHAV	F	4.00	38.00	7.00	6.00	11.00	15.00	32.00	17.00	11.00	60.00	64.00	82.00	72.00	59.00	16.00	16.00	16.00	16.00	3.00	14.00	9.00	560.00	3.00	0.84	5.00	8.00	56.00	
PROGATHAV	M	2.00	41.00	5.00	4.00	7.00	30.00	80.00	8.00	5.00	54.00	54.00	54.00	54.00	60.00	16.00	16.00	16.00	16.00	15.00	3.00	300.00	28.00	6.58	5.00	7.00	6.00	33.00	
PROGATHAV	F	2.00	47.00	6.00	2.00	3.00	62.00	168.00	104.00	6.00	45.00	42.00	26.00	29.00	NaN	NaN	NaN	NaN	12.00	1.00	3.00	36.00	11.84	4.00	2.00	9.00	37.00		
PROGATHAV	M	3.00	29.00	5.00	4.00	4.00	17.00	33.00	39.00	9.00	49.00	50.00	41.00	44.00	47.00	16.00	16.00	16.00	16.00	20.00	11.00	380.00	15.00	5.14	5.00	7.00	7.00	36.00	
PROGATHAV	F	5.00	42.00	8.00	4.00	9.00	35.00	60.00	9.00	30.00	40.00	40.00	43.00	41.00	60.00	16.00	16.00	16.00	16.00	23.00	15.00	350.00	40.00	11.36	5.00	8.00	6.00	66.00	
PROGATHAV	M	5.00	31.00	8.00	8.00	9.00	24.00	23.00	3.00	8.00	46.00	50.00	47.00	47.00	47.00	16.00	16.00	16.00	16.00	29.00	11.00	491.00	15.00	4.21	5.00	8.00	7.5	21.00	
PROGATHAV	F	4.00	30.00	5.00	5.00	5.00	7.00	23.00	69.00	46.00	41.00	46.00	44.00	49.00	51.00	16.00	16.00	16.00	16.00	15.00	10.00	499.00	7.00	1.40	5.00	7.00	5.00	42.00	
PROGASAS	M	3.00	30.00	8.00	5.00	7.00	23.00	56.00	33.00	9.00	46.00	50.00	62.00	62.00	56.00	16.00	16.00	16.00	16.00	NaN	NaN	476.00	40.00	8.61	4.00	7.00	5.00	43.00	
PROGKRS	M	4.00	30.00	5.00	4.00	8.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	F	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	M	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	F	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	M	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	F	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	M	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	F	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	M	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	F	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	M	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	F	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	M	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	F	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	M	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	F	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	M	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	F	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	M	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	F	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	M	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	F	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	M	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	F	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	M	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00
PROGKRS	F	4.00	25.00	4.00	5.00	4.00	20.00	44.00	17.00	64.00	71.00	76.00	59.00	60.00	60.00	16.00	16.00	16.00	16.00	0.00	28.00	12.00	633.00	5.00	0.78	5.00	8.00	7.00	28.00

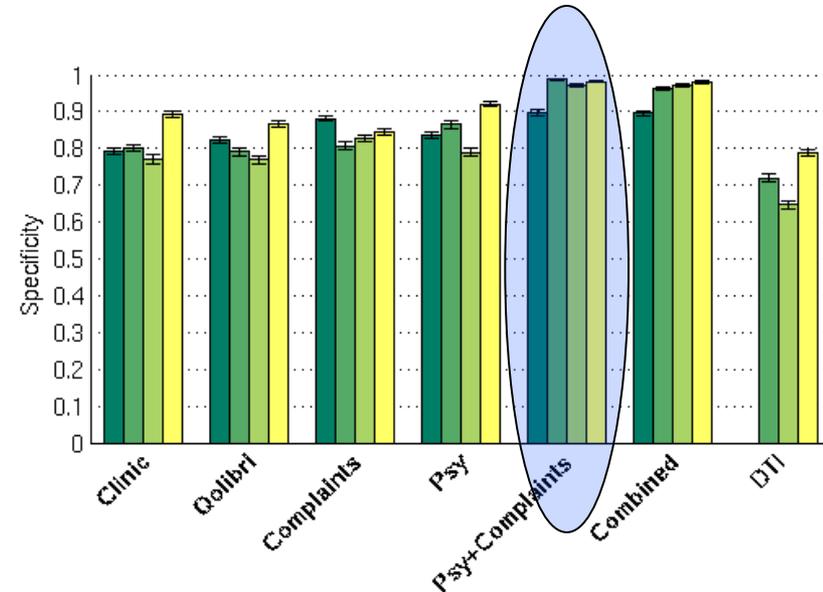
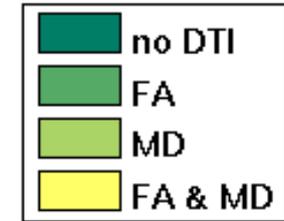
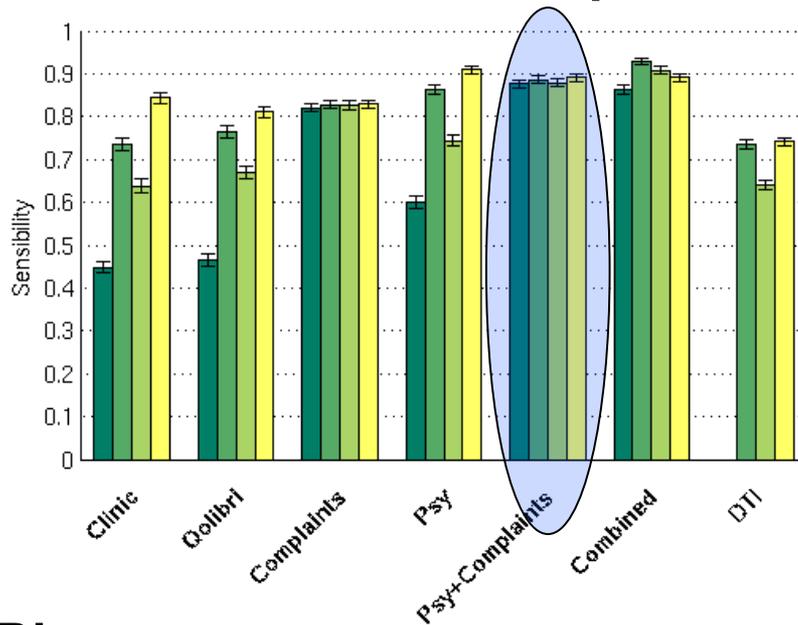
Prédiction multifactorielle et multicentrique des déficits comportementaux: *Etudes 1&2*



Prédiction multifactorielle et multicentrique des déficits comportementaux: *Etudes 1&2*



Prédiction multifactorielle et multicentrique des déficits comportementaux: *Etudes 1&2*



Biomarqueurs

- Pédoncules cérébelleux (moyen et pontine)
- Cingulaire et faisceau unciné droit

Neuropsychologie

- Empan total
- Trail Making Test B

Plaintes

- Dépression
- Troubles de mémoire
- Troubles de concentration
- Ralentissement de la pensée

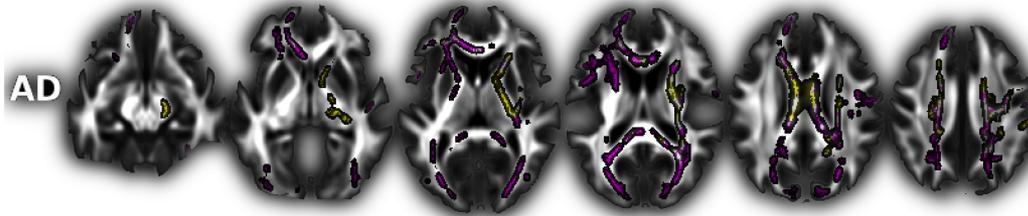
Messé et al., non publié.

Performance 96%
Sensibilité 88%
Spécificité 99%

Résumé

➤ **Présence de lésions diffuses chez les TCL (DTI)**

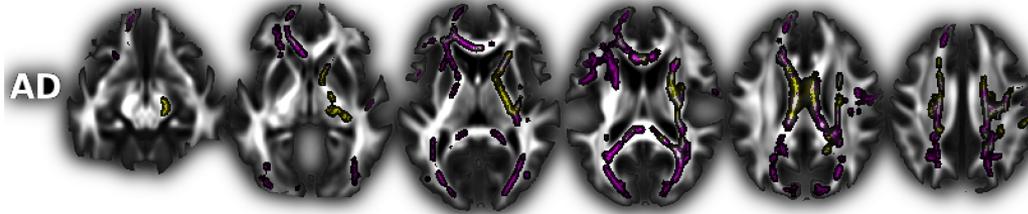
Atteinte axonale prononcée en présence d'un syndrome



Résumé

➤ **Présence de lésions diffuses chez les TCL (DTI)**

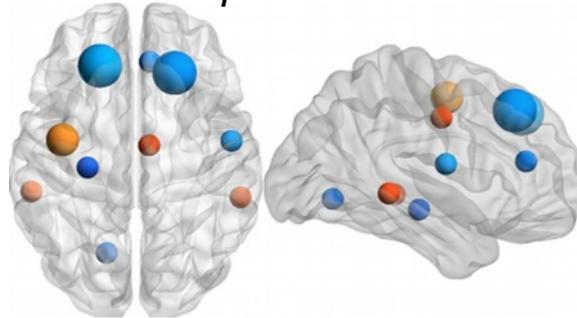
Atteinte axonale prononcée en présence d'un syndrome



➤ **Perturbations fonctionnelles suite au TCL (IRMf au repos)**

En présence d'un syndrome post-commotionnel

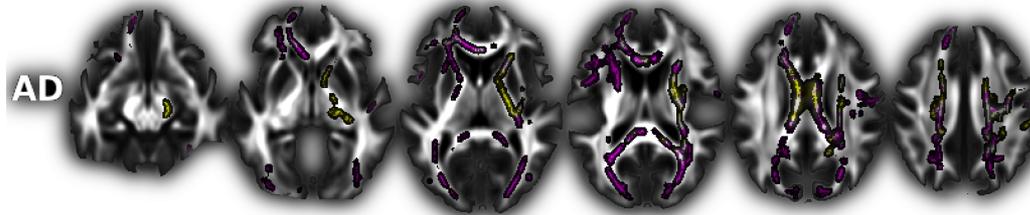
- ➔ *Atteinte du thalamus et des régions temporales en aiguë*
- ➔ *Atteinte des régions frontales supérieures en chronique*



Résumé

➤ **Présence de lésions diffuses chez les TCL (DTI)**

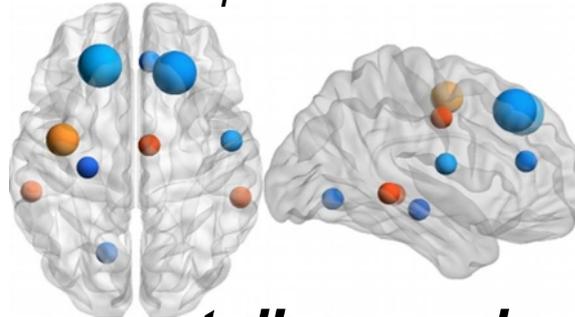
Atteinte axonale prononcée en présence d'un syndrome



➤ **Perturbations fonctionnelles suite au TCL (IRMf au repos)**

En présence d'un syndrome post-commotionnel

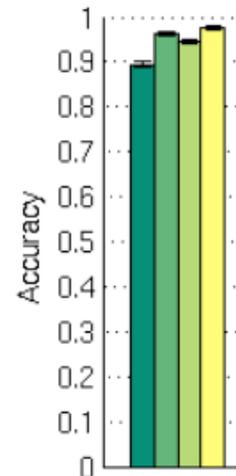
- ➔ *Atteinte du thalamus et des régions temporales en aiguë*
- ➔ *Atteinte des régions frontales supérieures en chronique*



➤ **Prédiction du développement d'un syndrome persistant**

Combinaison de mesures comportementales et d'imagerie

Performances aux alentours de 95% !!



Perspectives

➤ ***Corrélat comportementaux des déficits organiques***

- Quelles sont les régions cérébrales liées aux performances des différents tests cliniques et neuropsychologiques ?

Perspectives

➤ **Corrélat comportementaux des déficits organiques**

- Quelles sont les régions cérébrales liées aux performances des différents tests cliniques et neuropsychologiques ?

➤ **Reconsidérer les critères de pronostic**

- Objectiver les classements et les plaintes par la neuropsychologie et l'imagerie
- Dessiner de nouveaux critères autres que l'ICD10 ou le DSM-IV

NeuroRehabilitation 28 (2011) 167–180
DOI 10.3233/NRE-2011-0646
IOS Press

167

20th Anniversary Article

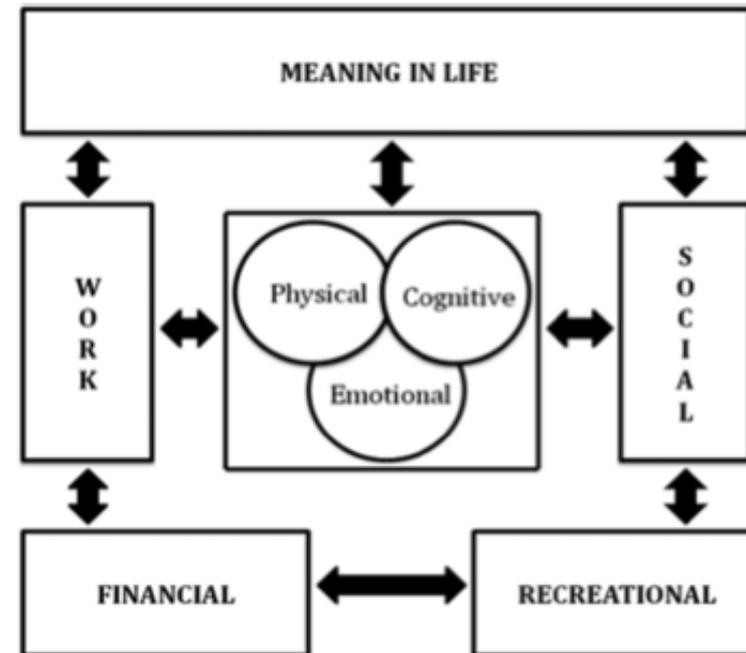
Mild traumatic brain injury and neural recovery: Rethinking the debate

Ronald M. Ruff

San Francisco Clinical Neurosciences, 909 Hyde Street, Suite 620, San Francisco, CA 94109, USA

E-mail: ronruff@mindspring.com

Abstract. A debate exists concerning whether a mild traumatic brain injury (MTBI) can cause permanent brain-based residuals. This debate is examined by reviewing meta-analytic studies that found no significant effect sizes between large samples of patients with and without MTBI at three months post-accident. In contrast, research studies with MTBI patients have captured cognitive deficits corroborated by positive neuroimaging, which supports the viewpoint that brain-based postconcussive disorders likely exist in a small minority of individuals. Ongoing hurdles that likely contribute to this debate are identified. This includes the lack of agreed upon definitions; substantial differences exist between the ICD-10 definition for Postconcussion Syndrome and the DSM-IV-TR definition for Postconcussional Disorder. Confining the debate to brain-based versus psychologically-based viewpoints results in a false dichotomy. Instead, a more refined sub-classification of the postconcussive complex is proposed that captures different constellations across the physical, emotional, and cognitive symptoms complex. Moreover, this diagnostic framework attempts to expand discipline-based approaches with a patient-based understanding.



Perspectives

➤ **Corrélat comportementaux des déficits organiques**

- Quelles sont les régions cérébrales liées aux performances des différents tests cliniques et neuropsychologiques ?

➤ **Reconsidérer les critères de pronostic**

- Objectiver les classements et les plaintes par la neuropsychologie et l'imagerie
- Dessiner de nouveaux critères autres que l'ICD10 ou le DSM-IV

NeuroRehabilitation 28 (2011) 167–180
DOI 10.3233/NRE-2011-0646
IOS Press

167

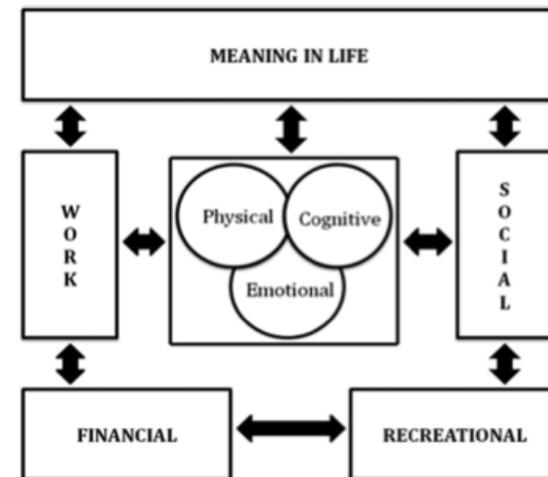
20th Anniversary Article

Mild traumatic brain injury and neural recovery: Rethinking the debate

Ronald M. Ruff

San Francisco Clinical Neurosciences, 909 Hyde Street, Suite 620, San Francisco, CA 94109, USA
E-mail: ronruff@mindspring.com

Abstract. A debate exists concerning whether a mild traumatic brain injury (MTBI) can cause permanent brain-based residuals. This debate is examined by reviewing meta-analytic studies that found no significant effect sizes between large samples of patients with and without MTBI at three months post-accident. In contrast, research studies with MTBI patients have captured cognitive deficits corroborated by positive neuroimaging, which supports the viewpoint that brain-based postconcussive disorders likely exist in a small minority of individuals. Ongoing hurdles that likely contribute to this debate are identified. This includes the lack of agreed upon definitions; substantial differences exist between the ICD-10 definition for Postconcussion Syndrome and the DSM-IV-TR definition for Postconcussional Disorder. Confining the debate to brain-based versus psychologically-based viewpoints results in a false dichotomy. Instead, a more refined sub-classification of the postconcussive complex is proposed that captures different constellations across the physical, emotional, and cognitive symptoms complex. Moreover, this diagnostic framework attempts to expand discipline-based approaches with a patient-based understanding.



➤ **Confirmer la prédiction via une étude à large échelle, internationale**

Merci de votre attention



Habib Benali

Guillaume Marrelec

Mélanie Pélégrini-Issac

Vincent Perlberg

...



Marc Tadié

Sophie Blancho

Nozar Aghakhani

...



Michèle Montreuil

Sophie Caplain

...

Inserm



Stéphane Lehéricy

Richard Lévy

Eric Bardinet

Romain Valabrègue

...





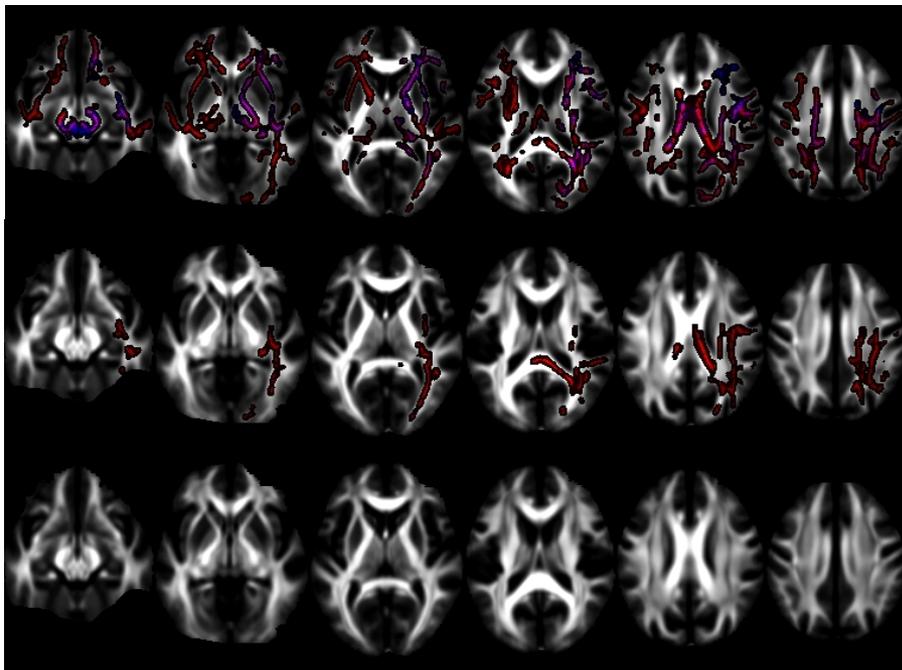


Association des lésions axonales diffuses aux déficits comportementaux: *Etude 2*

Tract-Based Spatial Statistics – TBSS

FA

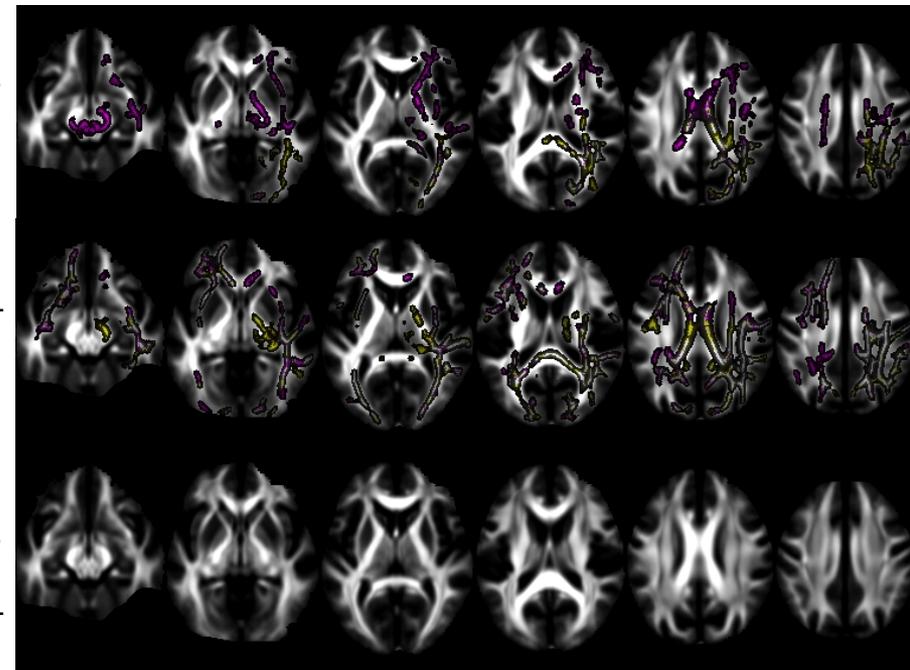
diffusivité radiale



PCS-
vs.
C

PCS+
vs.
C

PCS-
vs.
PCS+



$p < 0,05$ corrigé