

Neurologie des activités numériques et du calcul : un survol historique et anatomique

Michel Habib
CHU de Marseille



Assistance Publique
Hôpitaux de Marseille





Salomon HENSCHEN (1847-1930)

"cécité numérique" (trouble de la lecture des chiffres),
"agraphie numérique" (trouble de l'écriture des chiffres)
"aphasie pour les chiffres" (trouble de la production orale des chiffres)



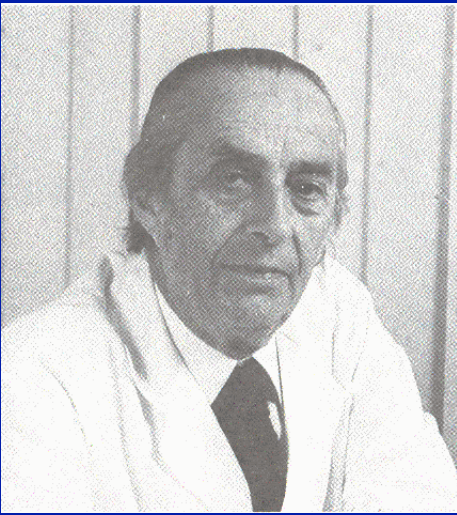
Hans BERGER (1873 - 1941)

acalculie primaire et acalculie secondaire



Karl KLEIST(1879-1961)

alexie et agraphie pour les nombres distinctes de la véritable acalculie
(= trouble du calcul mental sans alexie ni agraphie)
Importance du trouble visuo-spatial



Henri Hécaen (1912-1983)

- Hécaen et al. (1961) : 3 questions principales :
 - la classification des troubles
 - La spécificité des désordres (langage?, gnosies?, intelligence?)
 - La localisation des lésions.
- 183 patients : 3 groupes
 - Acalculie agraphique ou alexique
 - Acalculie spatiale (problèmes dans les calculs écrits, inversions, etc;..)
 - Anarithmésie : procédures du calcul



J. Gerstmann
1887- 1969

- 1924 : femme de 52 ans admise à la Clinique psychiatrique de Vienne pour des difficultés de mémoire et d'écriture
- hémianopsie droite, trouble du calcul et un défaut d'orientation pour la droite et la gauche de son propre corps.
- "agnosie digitale" = perte de la capacité à reconnaître, identifier, différencier, dénommer, sélectionner chacun des doigts de chaque main.
- 1927 : deux autres cas :
 - acalculie, agraphie, indistinction droite-gauche et agnosie digitale,
 - mais sans hémianopsie (qui devenait dès lors hors syndrome), mais avec une apraxie constructive.

Fingeragnosie. Eine umschriebene Störung der Orientierung am eigenen Körper. Wiener Klin Wochenschr 37:1010–1012 (1924)

Fingeragnosie und isolierte Agraphie; ein neues Syndrom. Z Ges Neurol Psychiat 1927; 108 : 152-77



A pure case of Gerstmann syndrome with a subangular lesion

Eugene Mayer,¹ Marie-Dominique Martory,¹ Alan J. Pegna,¹ Theodor Landis,² Jacqueline Delavelle³ and Jean-Marie Annoni¹

¹Neuropsychology Unit, ²Neurology Clinic and
³Neuroradiology Unit, Department of Radiology, Geneva
University Hospital, Switzerland

Correspondence to: Eugene Mayer, Neuropsychology Unit,
Neurology Clinic, Geneva University Hospital,
1211 Geneva 14, Switzerland
E-mail: euma@diogenes.hcuge.ch

Summary

The four symptoms composing Gerstmann's syndrome were postulated to result from a common cognitive denominator (Grundstörung) by Gerstmann himself. He suggested that it is a disorder of the body schema restricted to the hand and fingers. The existence of a Grundstörung has since been contested. Here we suggest that a common psychoneurological factor does exist, but should be related to transformations of mental images rather than to the body schema. A patient (H.P.) was studied, who presented the four symptoms of Gerstmann's syndrome in the absence of any other neuropsychological disorders. MRI showed a focal ischaemic lesion, situated subcortically in the inferior part of the left angular gyrus and reaching the superior posterior region of T1. The cortical layers were spared and the lesion was seen to extend to the

callosal fibres. On the basis of an extensive cognitive investigation, language, praxis, memory and intelligence disorders were excluded. The four remaining symptoms (finger agnosia, agraphia, right–left disorientation and dyscalculia) were investigated thoroughly with the aim of determining any characteristics that they might share. Detailed analyses of the tetrad showed that the impairment was consistently attributable to disorders of a spatial nature. Furthermore, cognitive tests necessitating mental rotation were equally shown to be impaired, confirming the essentially visuospatial origin of the disturbance. In the light of this report, the common cognitive denominator is hypothesized to be an impairment in mental manipulation of images and not in body schema.

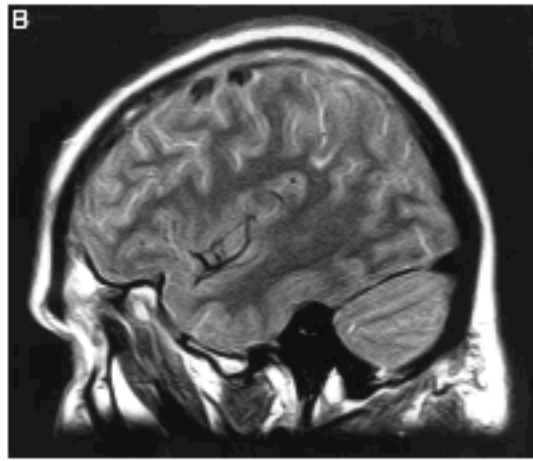
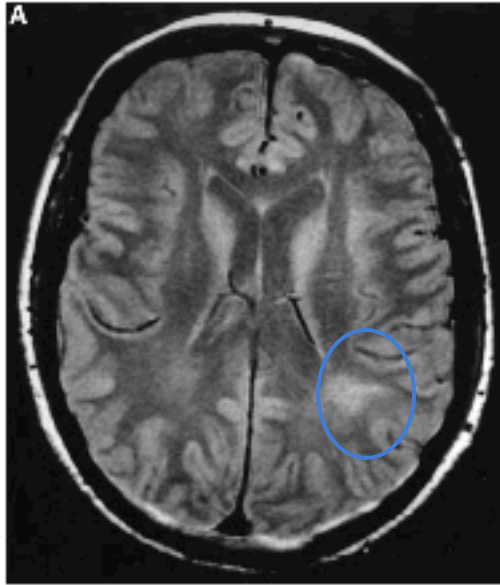


Fig. 2 Axial schematic plate according to the atlas of Talairach and Tournoux (Talairach and Tournoux, 1988) showing the subcortical lesion (arrow) and its topographic relationships with the angular gyrus (area 39).

A Disconnection Account of Gerstmann Syndrome: Functional Neuroanatomy Evidence

Elena Rusconi, PhD,^{1,2} Philippe Pinel, PhD,^{1,3,4} Evelyn Eger, MD,^{1,3,4} Denis LeBihan, MD, PhD,^{3,4}
Bertrand Thirion, PhD,³ Stanislas Dehaene, PhD,^{1,3,4} and Andreas Kleinschmidt, MD, PhD^{1,3,4}

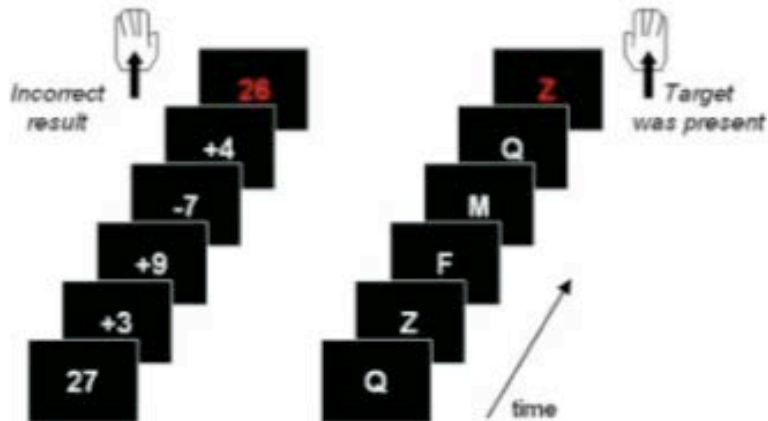
Objective: To examine the functional neuroanatomy that could account for pure Gerstmann syndrome, which is the selective association of acalculia, finger agnosia, left-right disorientation, and agraphia.

Methods: We used structural and functional neuroimaging at high spatial resolution in healthy subjects to seek a shared cortical substrate of the *Grundstörung* posited by Gerstmann, ie, a common functional denominator accounting for this clinical tetrad. We construed a functional activation paradigm that mirrors each of the four clinical deficits in Gerstmann syndrome and determined cortical activation patterns. We then applied fiber tracking to diffusion tensor images and used cortical activation foci in the four functional domains as seed regions.

Results: None of the subjects showed parietal overlap of cortical activation patterns from the four cognitive domains. In every subject, however, the parietal activation patterns across all four domains consistently connected to a small region of subcortical parietal white matter at a location that is congruent with the lesion in a well-documented case of pure Gerstmann syndrome.

Interpretation: Our functional neuroimaging findings are not in agreement with Gerstmann's postulate of damage to a common cognitive function underpinning clinical semiology. Our evidence from intact functional neuroanatomy suggests that pure forms of Gerstmann's tetrad do not arise from lesion to a shared cortical substrate but from intraparietal disconnection after damage to a focal region of subcortical white matter.

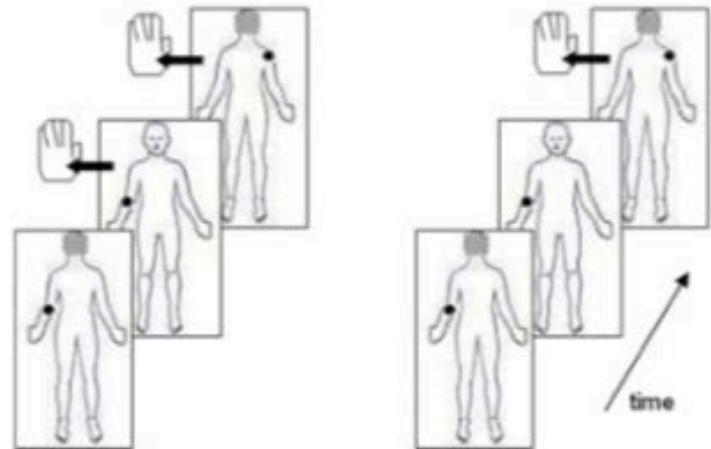
Calculation



Experimental task: mental adding and subtracting and result matching

Control task: letter memorisation and target matching

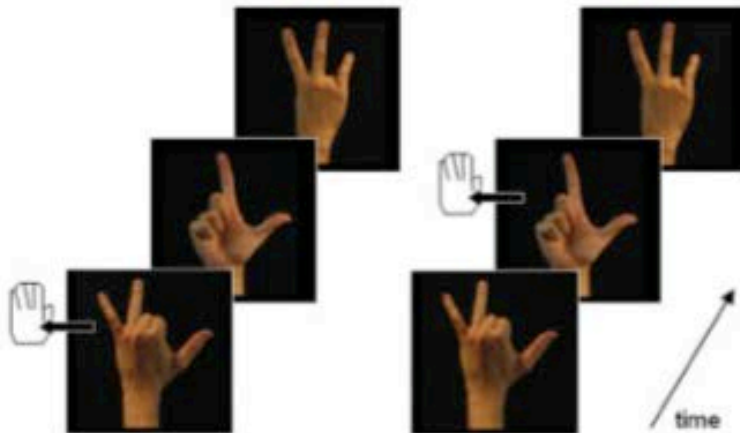
Left/Right Orientation



Experimental task: detection of a dot on the right side of the manikin

Control task: detection of a right-hand dot from the observer's point of view

Finger Gnosis



Experimental task: detection of an extended ring finger

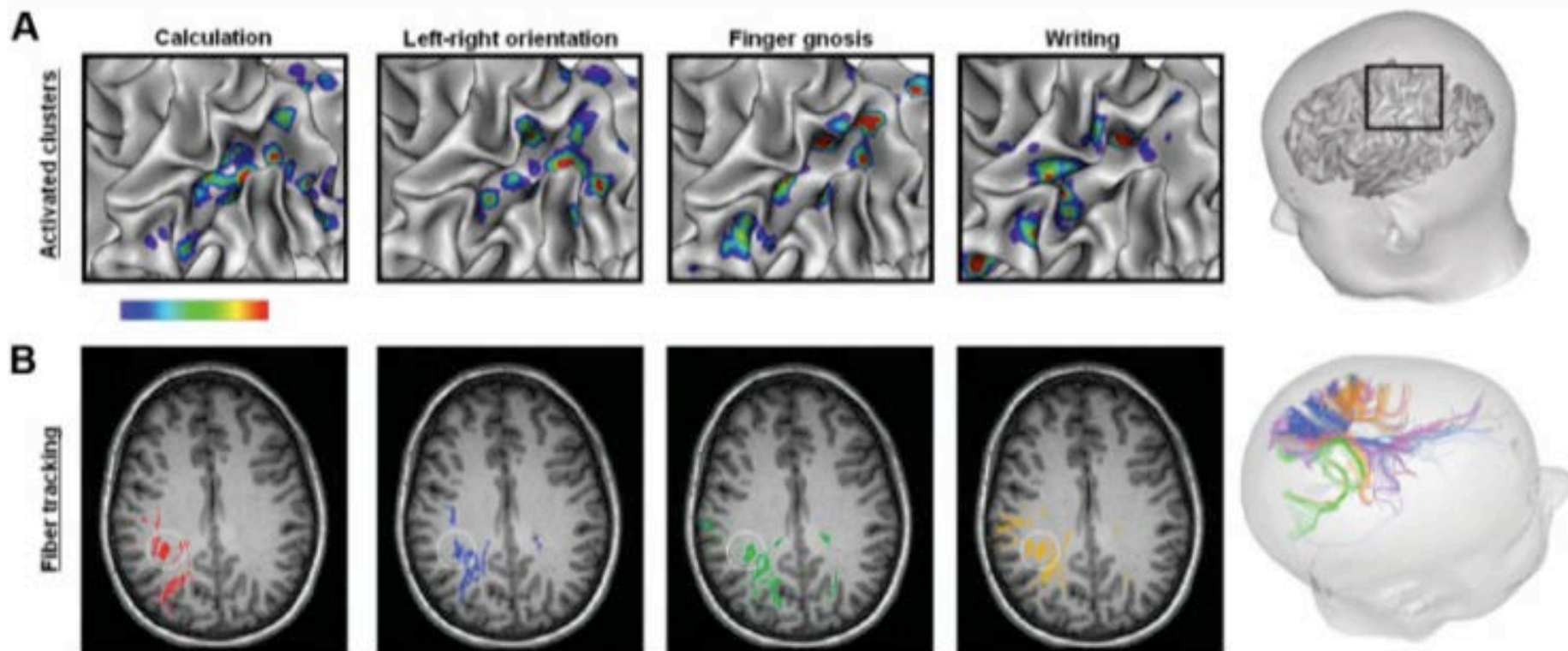
Control task: detection of a visible palm

Writing



Experimental task: write pseudowords to dictation

Control task: hatch during pseudowords presentation



A la recherche d'un modèle
neuropsychologique



Xavier Seron

Modèle de Séron et Deloche, 1987 : un modèle de transcodage

- Observation de patients adultes acalculiques après lésion cérébrale
- Erreurs de type lexical ou syntaxique
 - Deux cent quatre transcrit : 209; 3005 transcrit huit mille cinq
 - Deux cent quarante quatre transcrit : 200404; 204 lu deux mille quatre
- Le lexique est partagé en trois classes distinctes : les unités, les particuliers et les dizaines chaque nombre occupe une place propre dans chacune de ces trois classes
 - La troisième place est occupée par 3 dans la classe des unités, 13 pour les particuliers et 30 pour les dizaines
 - 12, 13 et 15 occupent des places distinctes dans une même classe



Les patients peuvent se tromper de classe mais pas de place ou vice-versa

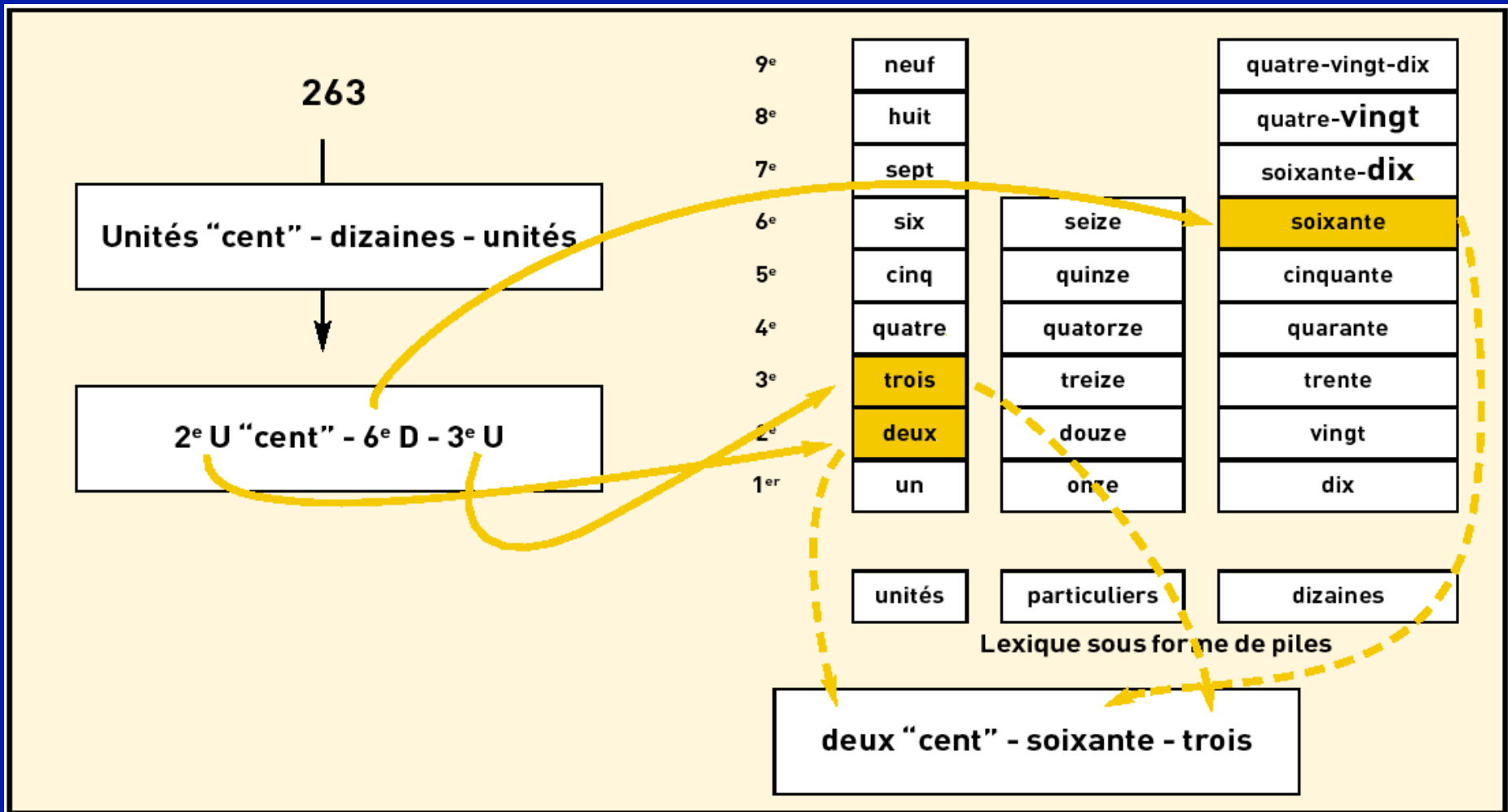
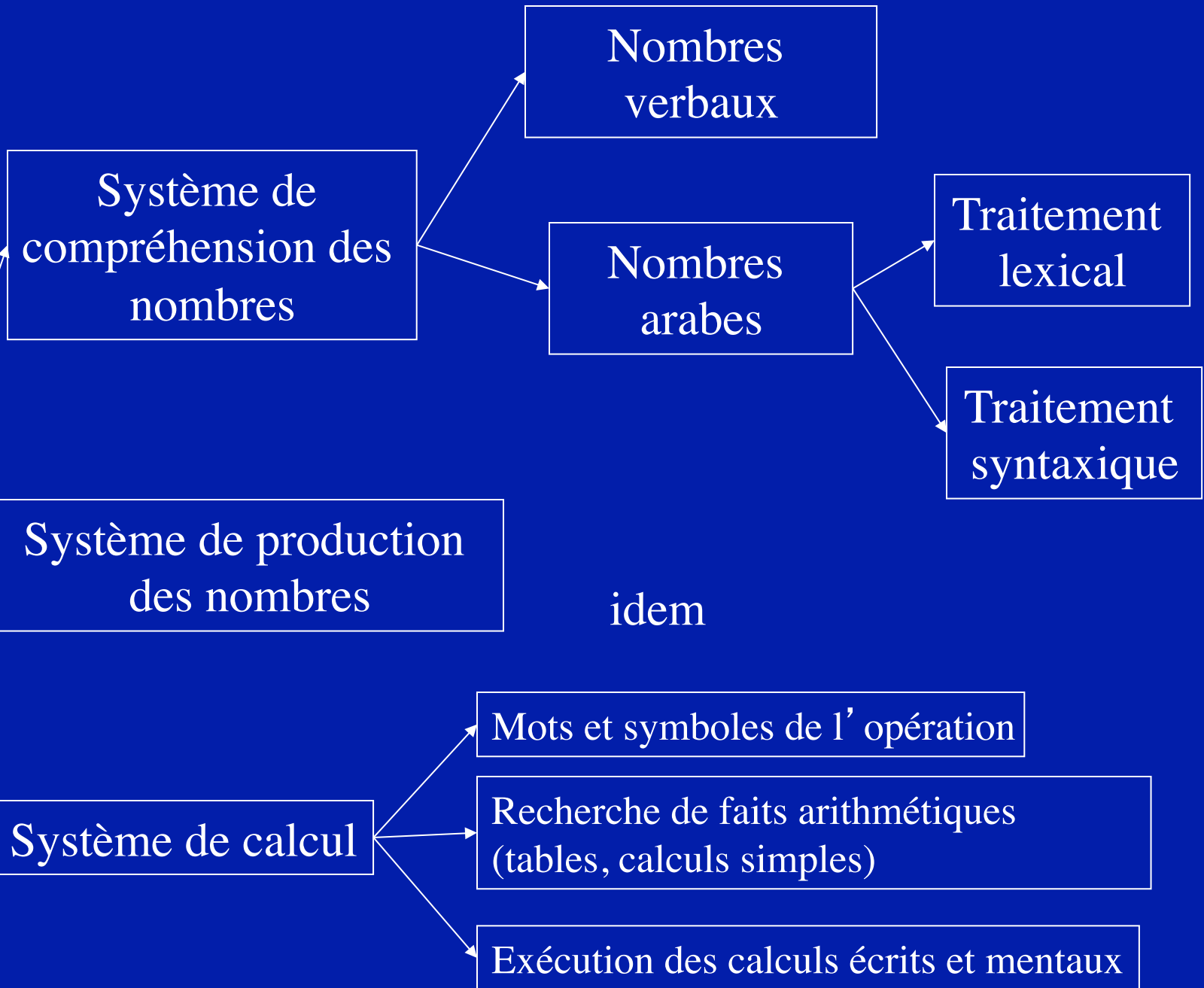
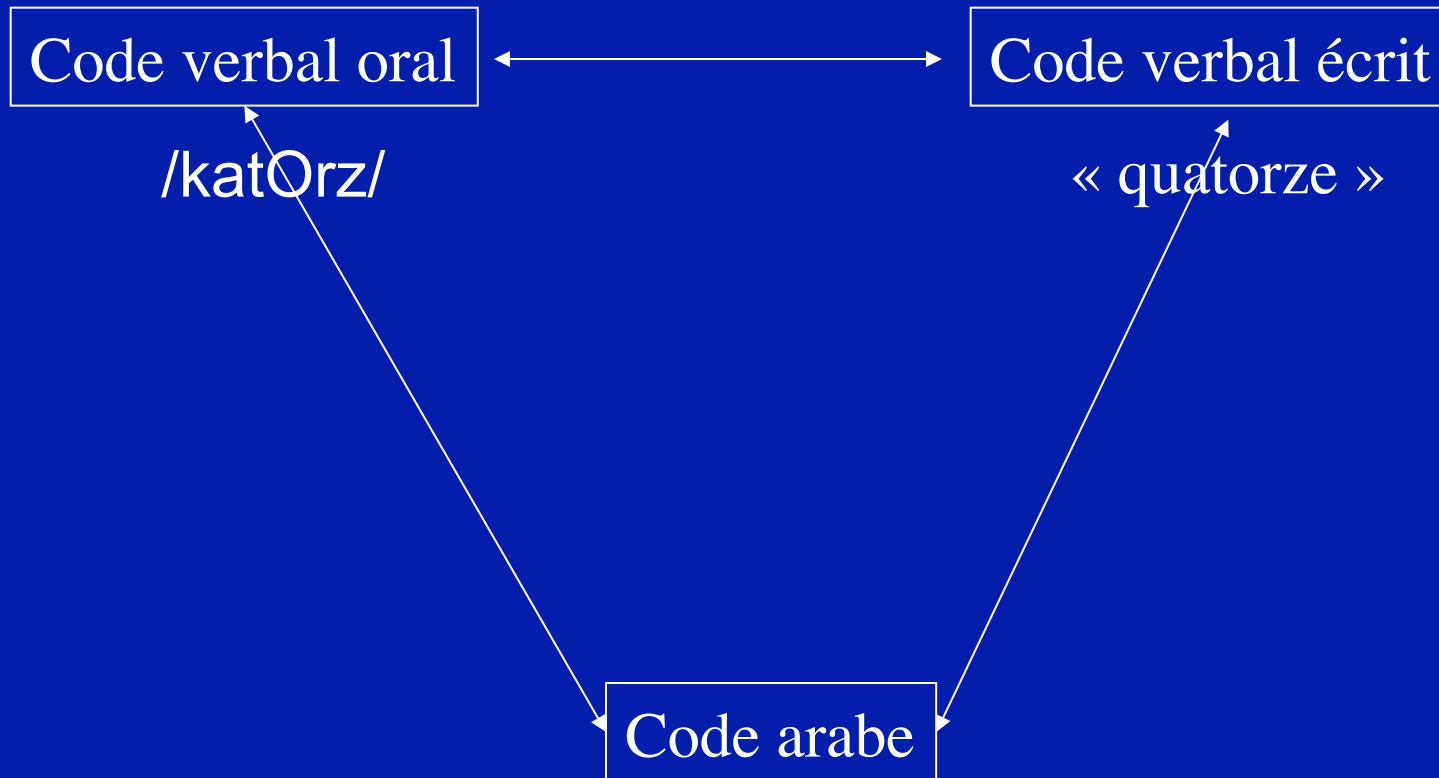


Figure 1 - Aspect cognitif de la lecture à haute voix du nombre "263".

SYSTÈME SÉMANTIQUE





14

→ Batterie d'examen clinique de chaque code et de chaque transcodage

Modèle de Mc Closkey : justification

- Déficit isolé de la production des nombres arabes : McCloskey et al., 1985 : sujet H.Y.: fait 15% d'erreurs (p.e. : 902 lu « neuf six cent »). Aucun problème de compréhension des nombres lus (comparaisons de magnitudes, vérification de problèmes)
- Déficit isolé de la reconnaissance des signes opératoires : Ferro et Botelho, 1980 : reconnaît tous les nombres et les symboles non numériques, mais pas les signes opératoires (d'où difficultés majeures dans les calculs posés)
- Déficit isolé de la récupération des faits arithmétiques : Warrington, 1982 : cas DRC : traitement des nombres et procédures mathématiques : intacts. Egalement dissociation inverse : respect des faits arithmétiques



Modèle sémantique par opposition au modèle asémantique de Deloche et Séron

Modèle de Mc Closkey

SYSTÈMES DE CALCUL

Traitement des mots ou
des symboles
opérateurs

Procédures de calcul

Stock des faits
arithmétiques

Lexique
graphémique

Lexique
phonologique

Syntaxe du
système verbal

Lexique arabe

Syntaxe du
système arabe

Représentation
sémantique

Lexique
graphémique

Lexique
phonologique

Syntaxe du
système verbal

Lexique arabe

Syntaxe du
système arabe

COMPRÉHENSION DES NOMBRES

PRODUCTION DES NOMBRES

TWO MENTAL CALCULATION SYSTEMS: A CASE STUDY OF SEVERE ACALCULIA WITH PRESERVED APPROXIMATION

STANISLAS DEHAENE* and LAURENT COHEN†

*INSERM & CNRS Laboratoire de Sciences Cognitives et Psycholinguistique, 54 Bd Raspail, F-75250 Paris cedex 06, France and †Clinique des Maladies du Système Nerveux, Pavillon Charcot, Hôpital de la Salpêtrière, 47 Bd de l'Hôpital, 75651 Paris cedex 13, France

(Received 5 April 1990; accepted 3 July 1991)

- Calcul exact versus calcul approché.
- "M. Nau" (Dehaene & Cohen, 1991) :
- aphasique + dyslexie profonde
 - Acalculie massive : ne peut dire « $2 \times 2 = ?$ »
 - Peut faire un calcul approximatif : écarte immédiatement " $2+2=9$ ", choisit la réponse la plus plausible entre " $3+5=4$ ou 9 "
 - Aucune difficulté à donner des réponses approchées : une année comprend environ 350 jours, neuf enfants dans une classe c'est peu, une douzaine "c'est 6 ou 10"
 - Hypothèse de l'hémisphère droit

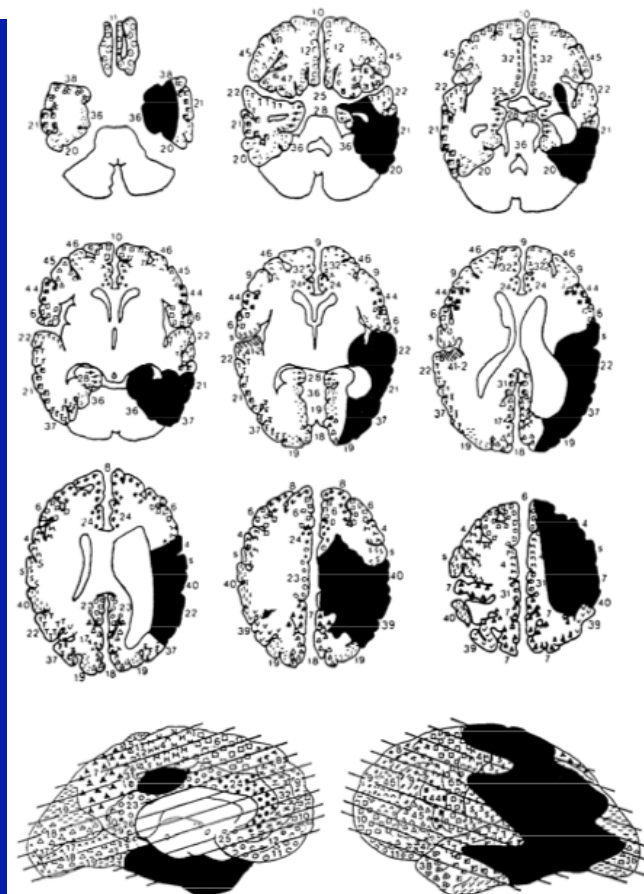


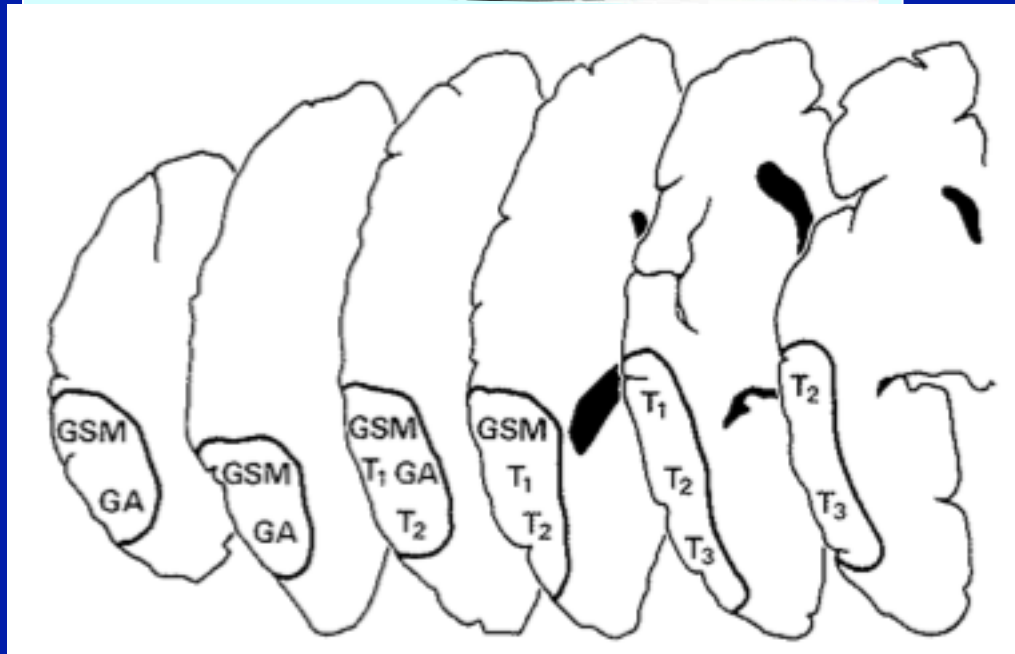
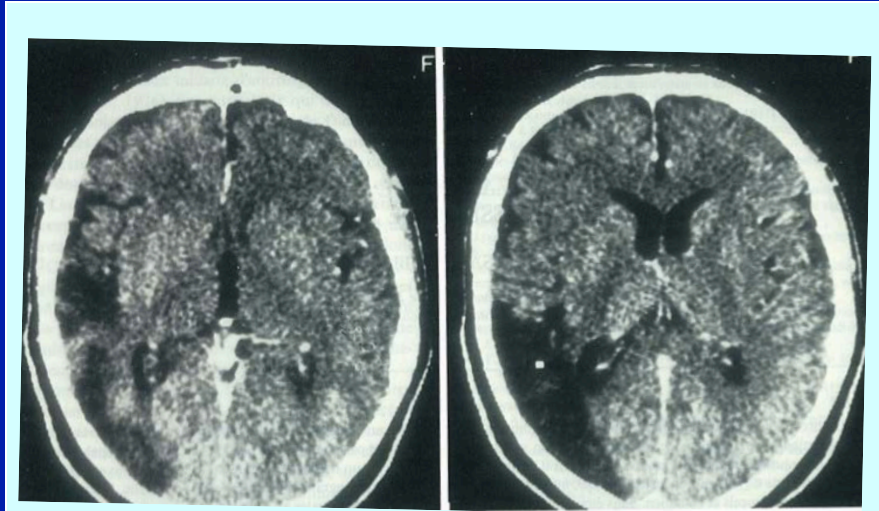
Fig. 1. Reconstruction of N.A.U.'s brain on the basis of CT scan using templates from DAMASIO and DAMASIO [9]. The lesioned left-hemisphere is represented on the right side of transversal sections.

Assal G, Jacot-Descombes C. Intuition arithmétique chez un acalculique. Rev Neurol 1984;5:374–5.

- Homme de 54 ans, musicien de haut niveau, bilingue français italien
- AVC embolique suite à une opération : aphasie de Wernicke, sans amusie significative (Assal & Buttet, 1983)
- Syndrome de Gerstmann typique (agraphie, sauf écriture musicale, confusion droite/gauche, agnosie digitale avec hémianopsie droite)
- CT scan : aire hypodense partie post de T1, T2 et T3 + GA et GSM
- Persistance 6 mois après d'une acalculie sévère, tant pour le calcul mental (3/20) qu'écrit (5/20), mais curieuse dissociation : en **choix multiple** , plus de 75% de bonnes réponses, et aucune réponse aberrante = performance idem témoins de son âge

(ex: combien font $13+12$: 22, 25, 27, 35, 81)

Il dit ne plus savoir calculer; il n'a pas l'impression que les réponses fournies en choix multiple se fondent sur un effort conscient de calcul, "je contrôle mal mes réponses" c'est ainsi qu'il exprime son incertitude, ajoutant qu'il a conservé tout au plus "une sorte d'intuition".



Atteinte lobule pariétal inférieur Gche, atteinte probable du sillon intra-pariétal?

Rôle de l'hémisphère droit?

CEREBRAL PATHWAYS FOR CALCULATION: DOUBLE DISSOCIATION BETWEEN ROTE VERBAL AND QUANTITATIVE KNOWLEDGE OF ARITHMETIC

Stanislas Dehaene¹ and Laurent Cohen²

(¹INSERM, CNRS and EHESS, Laboratoire de Sciences Cognitives et Psycholinguistique, Paris, France; ²Service de Neurologie, Hôpital de la Salpêtrière, Paris, France)

2 cas « d'anarithmie »

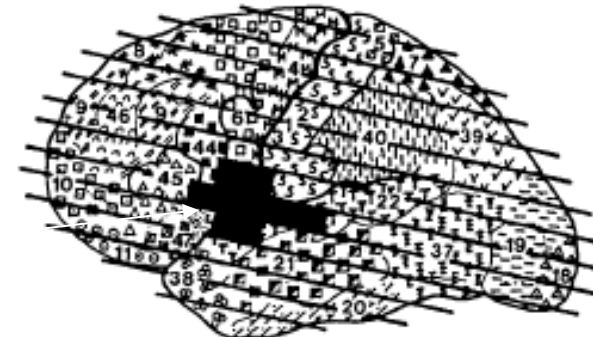
Cas 1 : lésion sous corticale gauche

- empan 4/3
- déficit dans les faits arithmétiques ($9 \times 8 = (10 \times 8) - 8$).
- 10% d'erreurs en soustraction

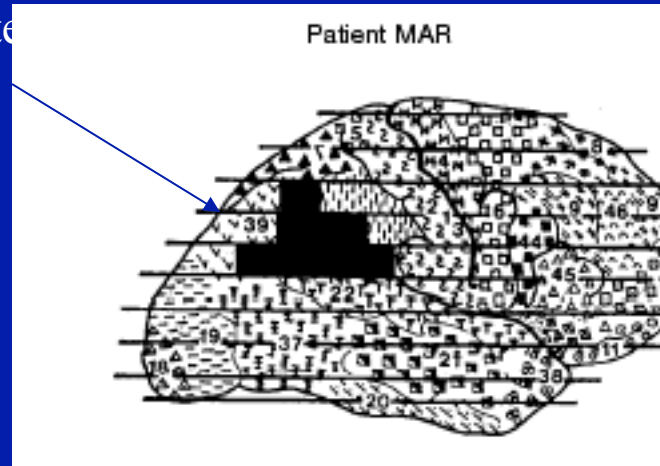
Cas 2 : lésion pariétale inférieure droite
synd de Gerstmann (gaucher)

- empan 5/2
- 40% erreurs en multiplications
- 70% erreurs en soustractions

Patient B00



Patient MAR



Ccl : a left subcortical network contributes to the storage and retrieval of rote verbal arithmetic facts, while a bilateral inferior parietal network is dedicated to the mental manipulation of numerical quantities.

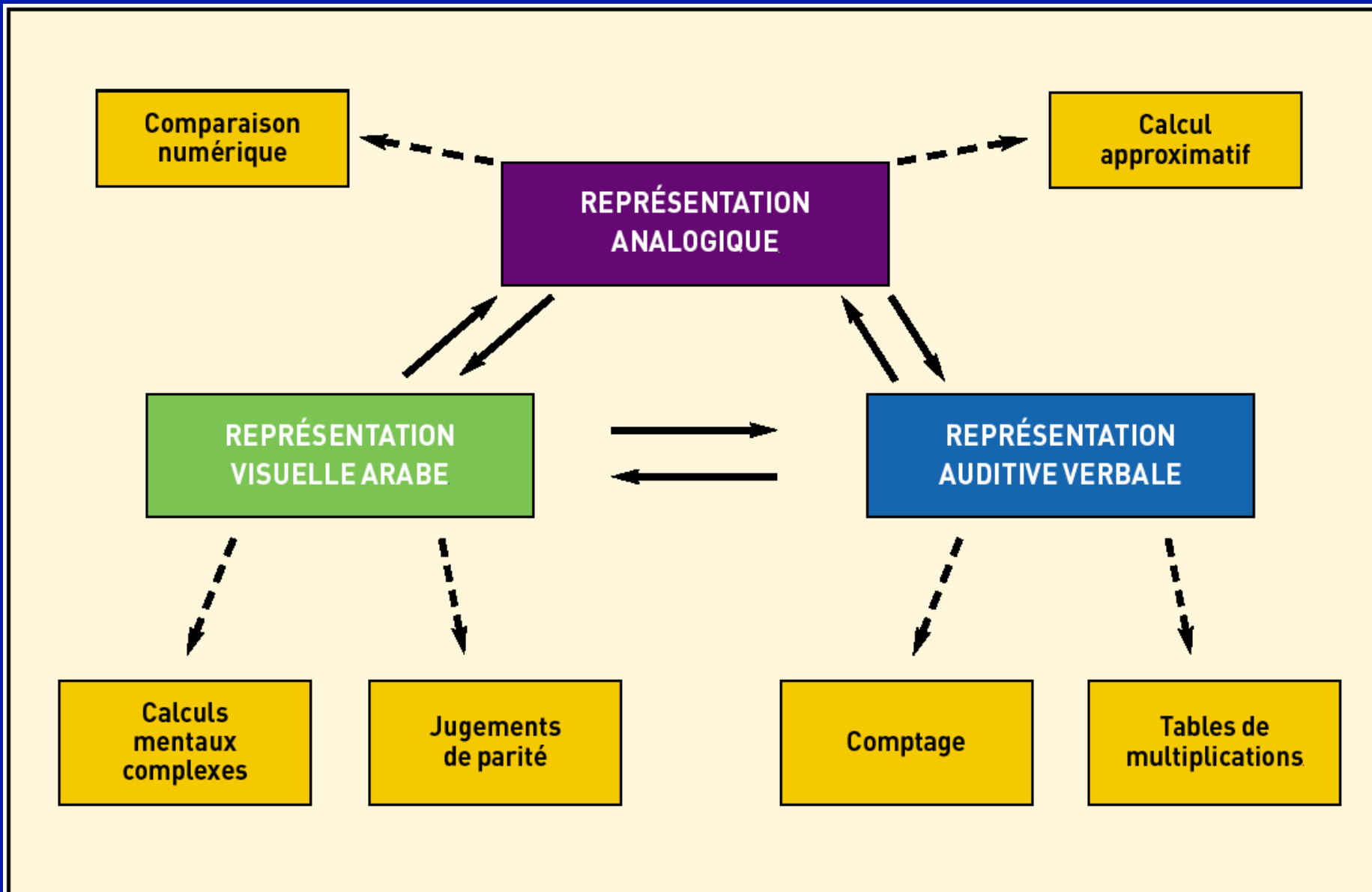


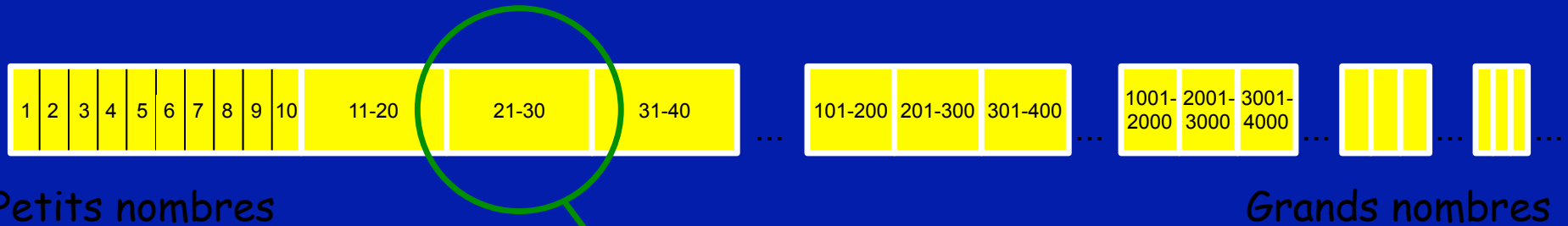
Figure 2 - Le modèle du "triple code" de Dehaene et Cohen.

Modèle du triple code (Dehaene et Cohen, 1995)

- Chaque type de représentation (analogique, auditivo-verbale et visuelle-arabe) est impliqué dans un traitement particulier du nombre.
- Chaque opération a un code unique pour l'entrée et la sortie
- Les trois composantes ont des mécanismes de traduction qui leur permettent de communiquer entre elles
- La représentation analogique peut être comparée à une ligne numérique et d'autant plus compressée et donc d'autant moins précise qu'on avance dans les grands nombres : utile dans la comparaison des nombres et le calcul approximatif
- Le système des nombres arabes manipule les chiffres arabes dans une grille spatiale et est utilisé dans les tâches de jugement de parité et les calculs à plusieurs chiffres.
- Le système auditivo-verbal utilise les modules généraux du langage et a accès aux tables d'addition et de multiplication stockées en mémoire à long terme.

Ligne numérique mentale:

- Orientée de gauche à droite
- Logarithmique



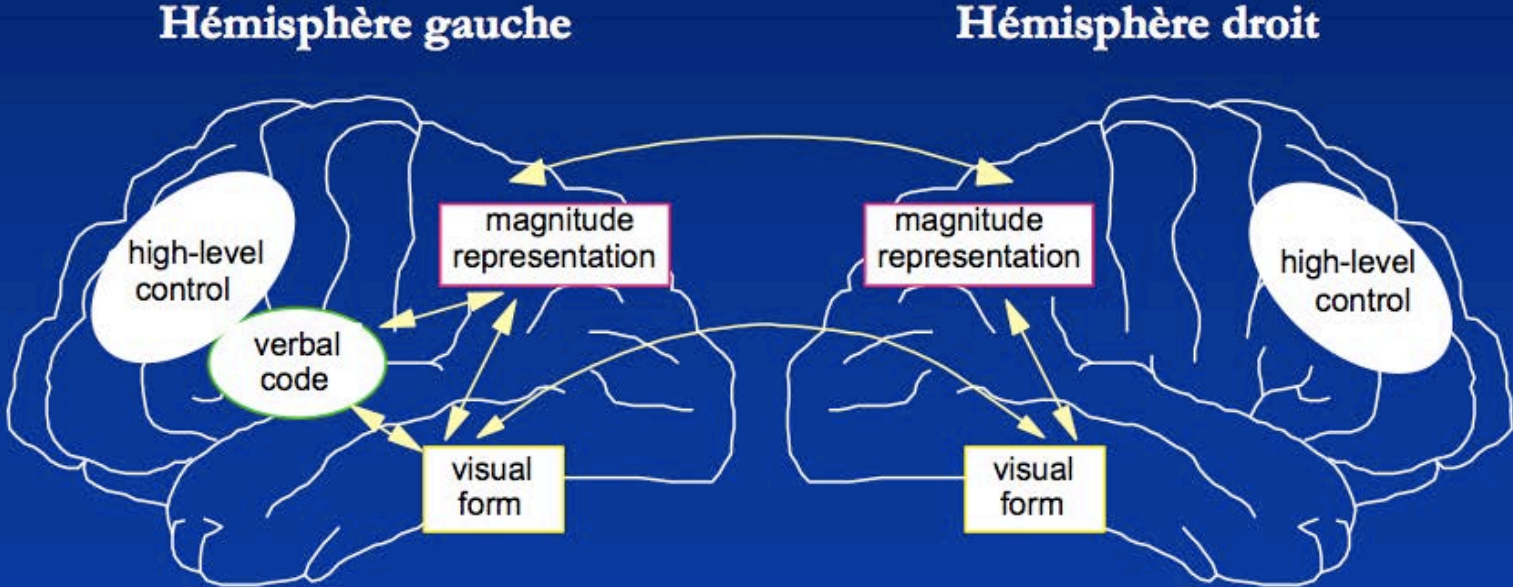
Activation des représentations analogiques des nombres proches



--> effet de distance

Le modèle du "triple code"

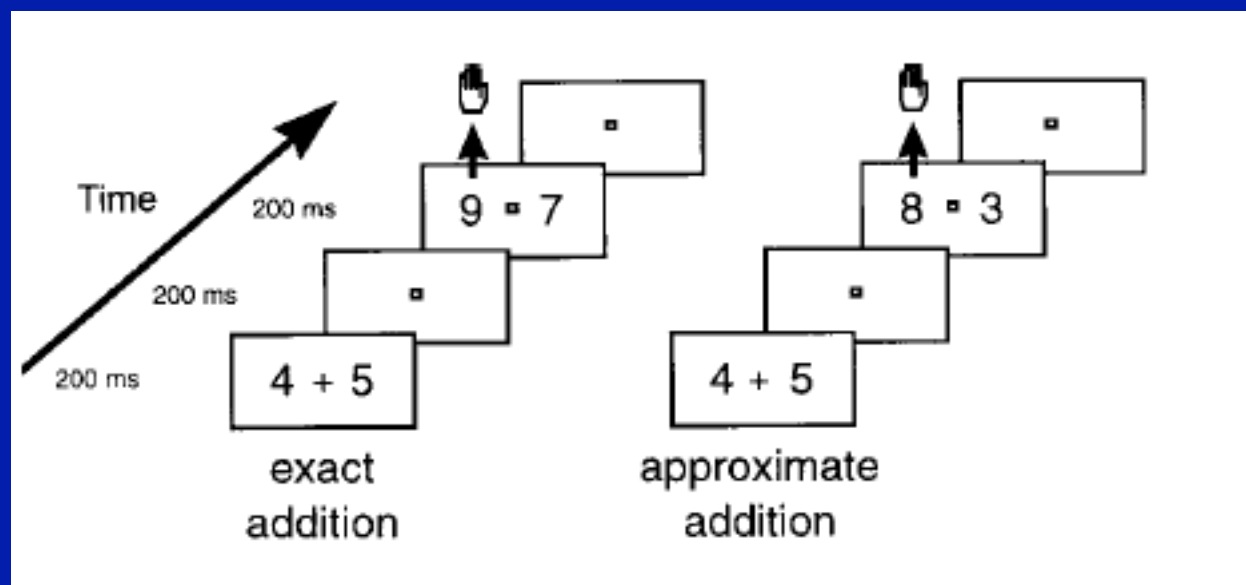
(Dehaene & Cohen, 1995)

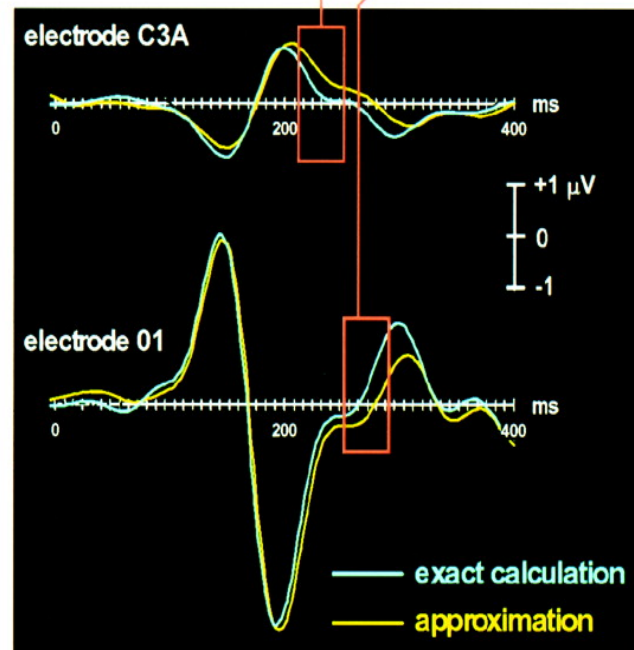
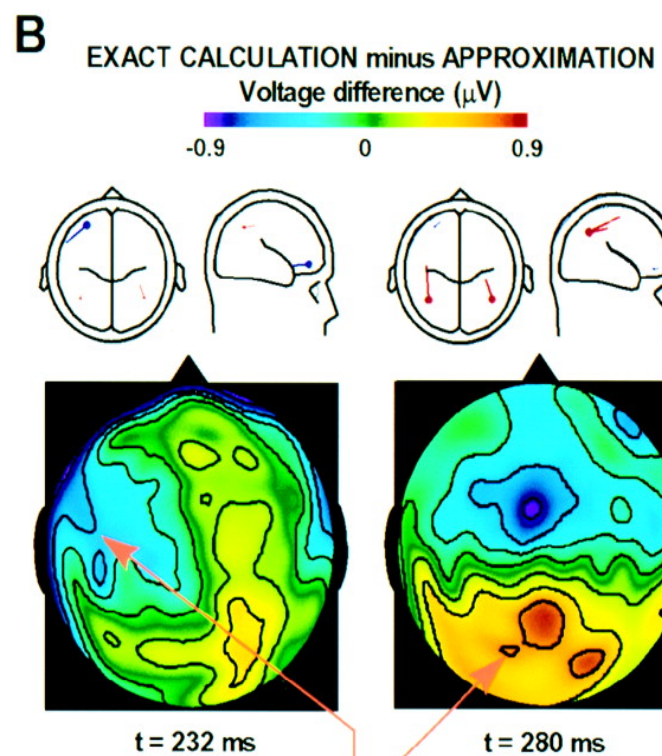
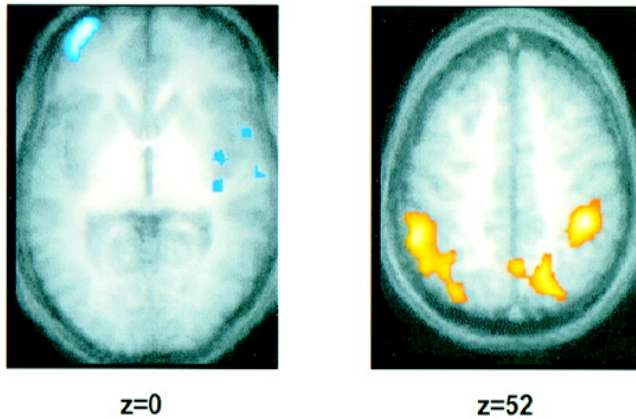
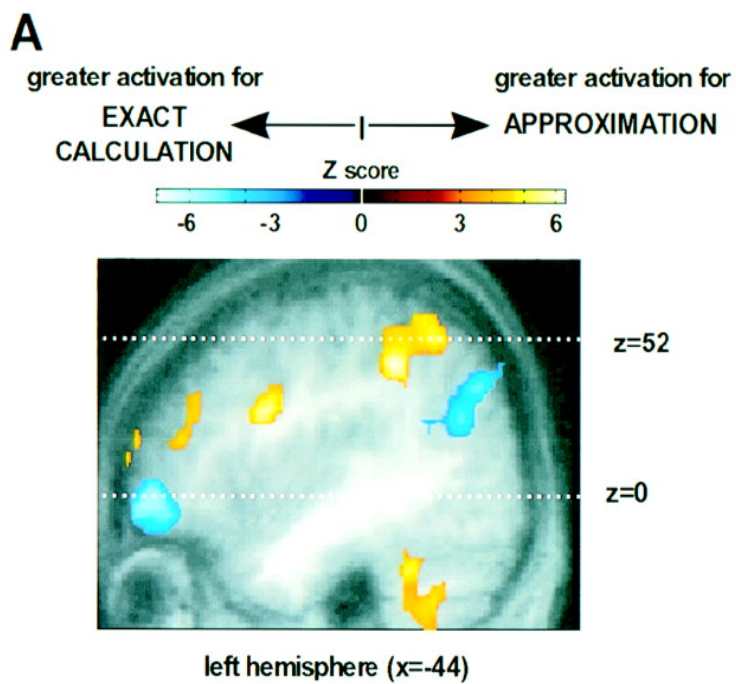


Dehaene, S. (1992). *Cognition*, 44, 1-42.
Dehaene, S., & Cohen, L. (1995). *Mathematical Cognition*, 1, 83-120.

Sources of Mathematical Thinking: Behavioral and Brain-Imaging Evidence

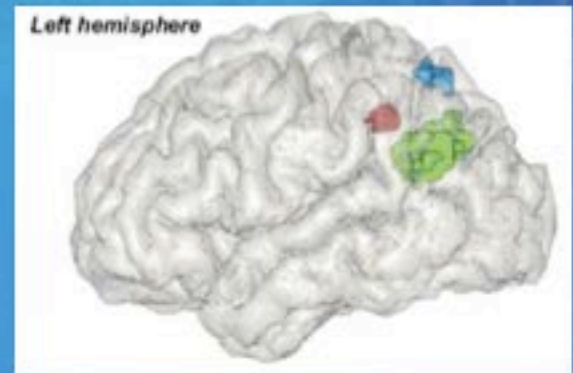
S. Dehaene,^{1*} E. Spelke,² P. Pinel,¹ R. Stanescu,¹ S. Tsivkin²



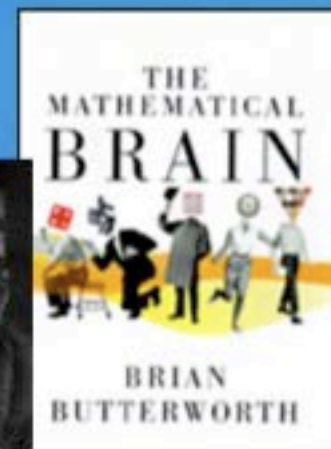
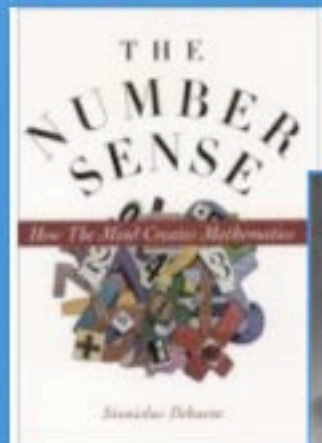


Numerical cognition

- Study of representation of number in the brain
- Methods: Animals, infants, cross-cultural linguistics, brain imaging, cognitive psychology
- Good introductory books:



Stanislas
Dehaene



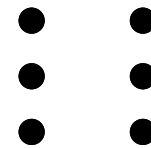
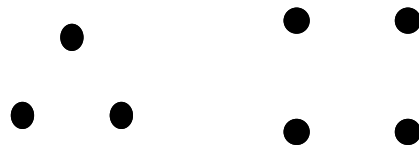
Un dyscalculique prototypique : Charles W (B. Butterworth)

- Charles W
 - Degree in psychology; postgraduate qualifications; always very bad at maths at school; finds shopping extraordinarily difficult. Takes 4-5 times as long as normals adding single digits; cannot subtract two digit numbers. Always calculates on his fingers (which makes multiplication hard).
 - Compensated dyslexic

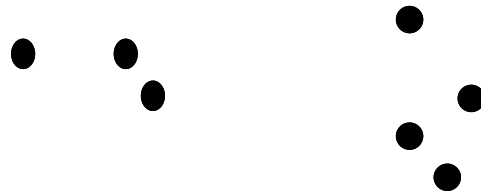
Subitizing (1-4)

Counting (6-9)

CANONICAL



RANDOM



6

5

2

9

8

7

Stroop conditions

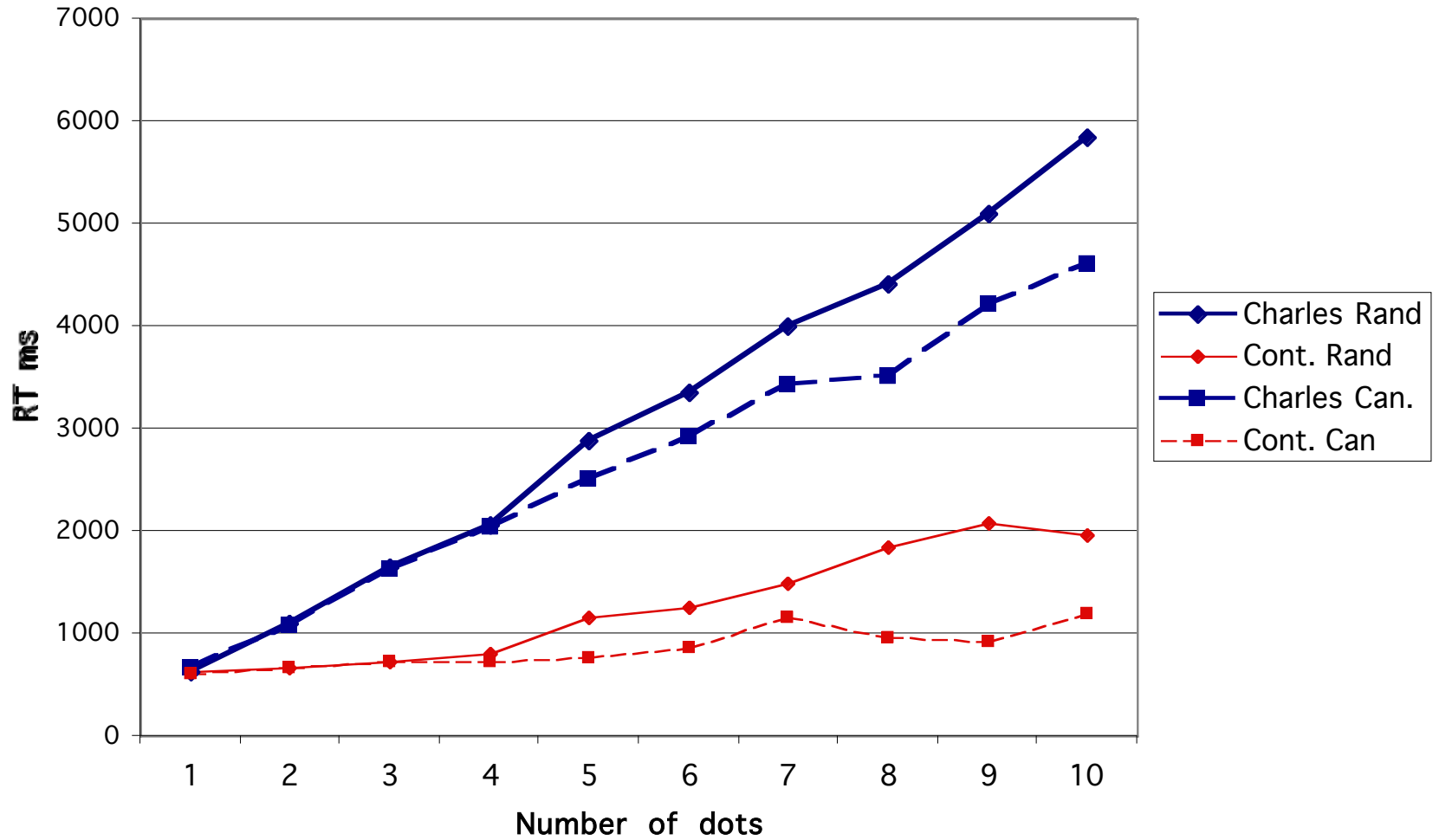
<i>Tâche</i>	Neutre (12)	Congruent (12)	Incongruent (12)
Numérique	3 6	3 6	3 6
Physique	3 3	3 6	3 6

2 différences de taille numérique : 1 (ex 2;3) et 5 (ex 7;2)

2 différences de taille physique : 0,3/0,5 cm et 0,6/1cm

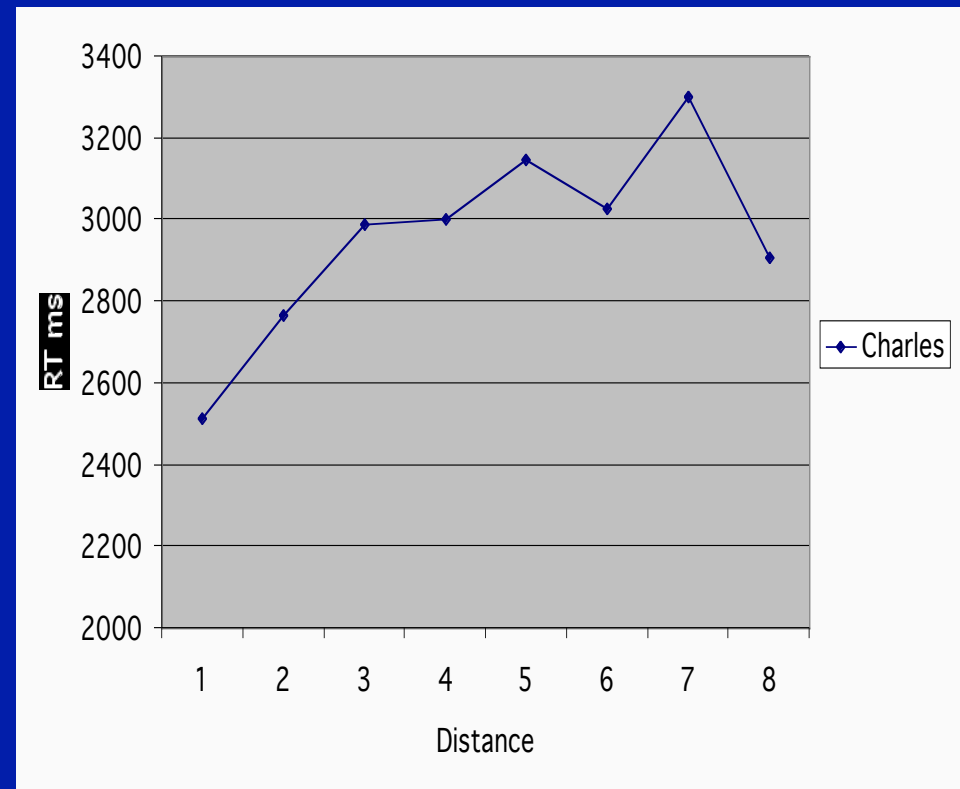
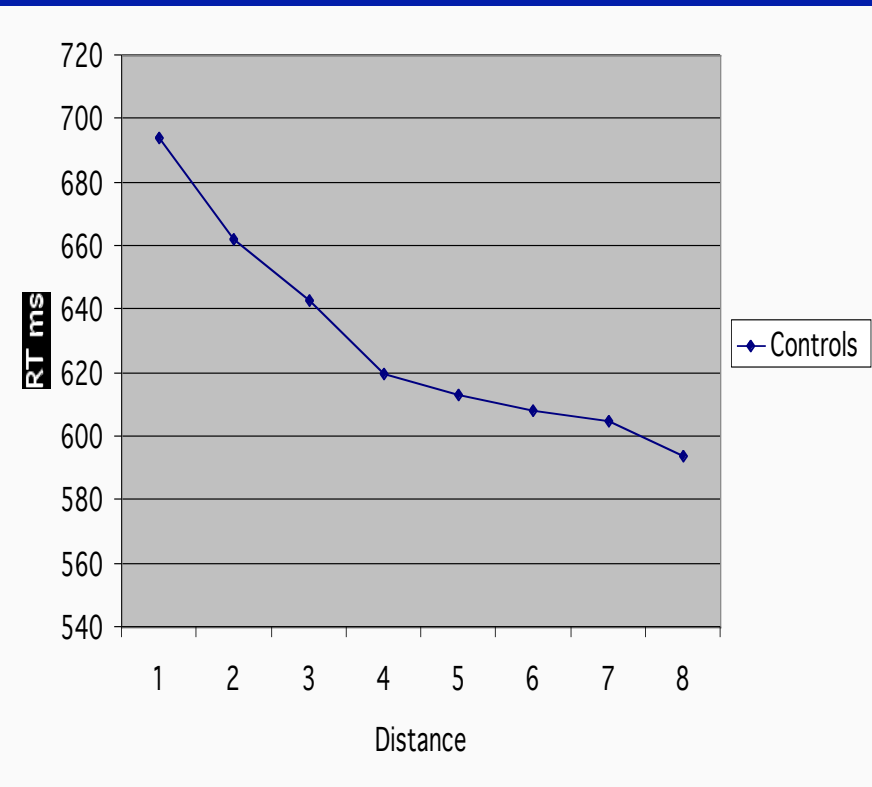
Réponse : appuyer sur la touche du côté du plus grand nombre

Charles vs controls: dot enumeration

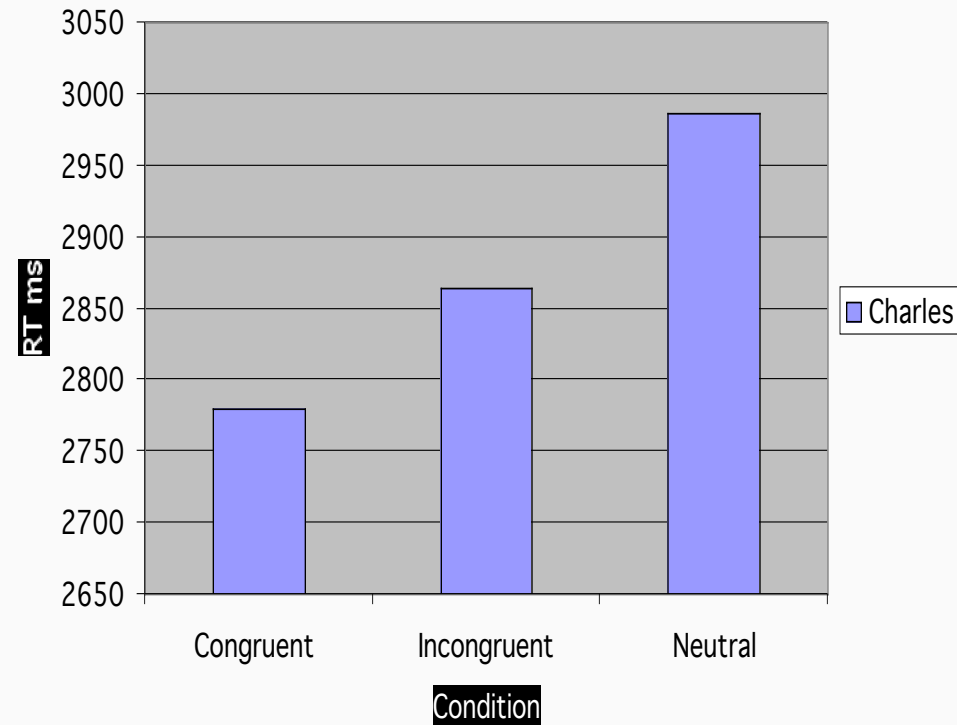
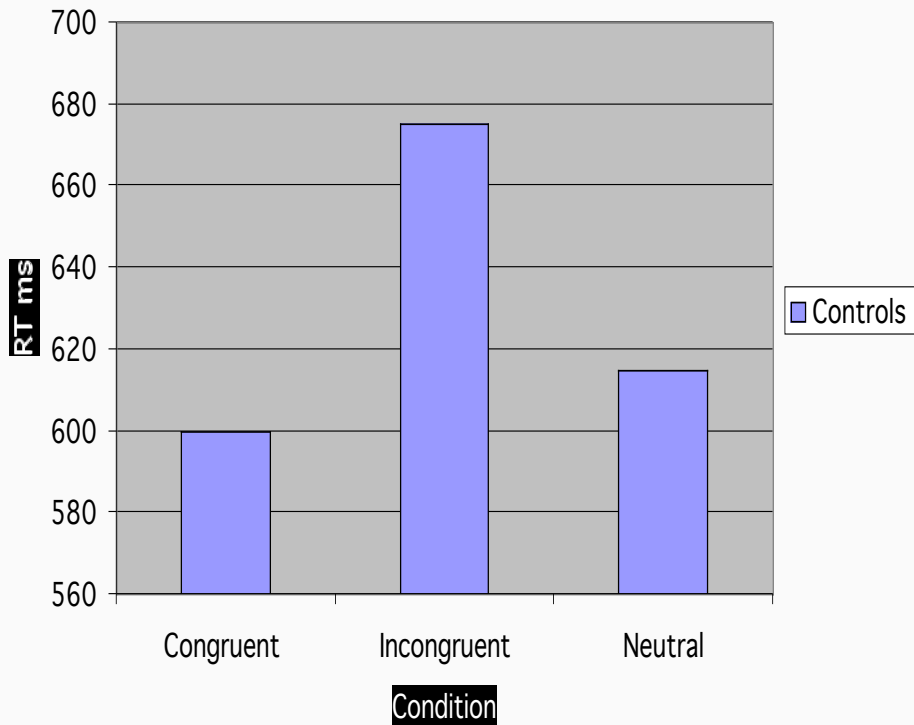


Charles vs controls: number comparison

Distance effect



Number stroop. Charles vs controls



interférence

facilitation



ELSEVIER
MASSON

available at www.sciencedirect.com

ScienceDirect

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



Special issue: Original article

Basic numerical processing in left intraparietal sulcus (IPS) acalculia

Sarit Ashkenazi^{a,*}, Avishai Henik^{a,**}, Gal Ifergane^b and Ilan Shelef^c

Ingénieur de 67 ans, excellent en maths auparavant, devenu acalculique et dysgraphique après un AVC.

Comparé à 4 témoins ingénieurs de même âge et niveau de formation. Lésion touche spécifiquement IPS gauche

Table 1 – The WAIS III index scores

Test	Index scores	Percentile (%)
Verbal comprehension	112	79
Perceptual organization	116	86
Working memory	108	70
Processing speed	114	82

Note: Test average = 100, standard deviation = 15. All scores are standardized by age.

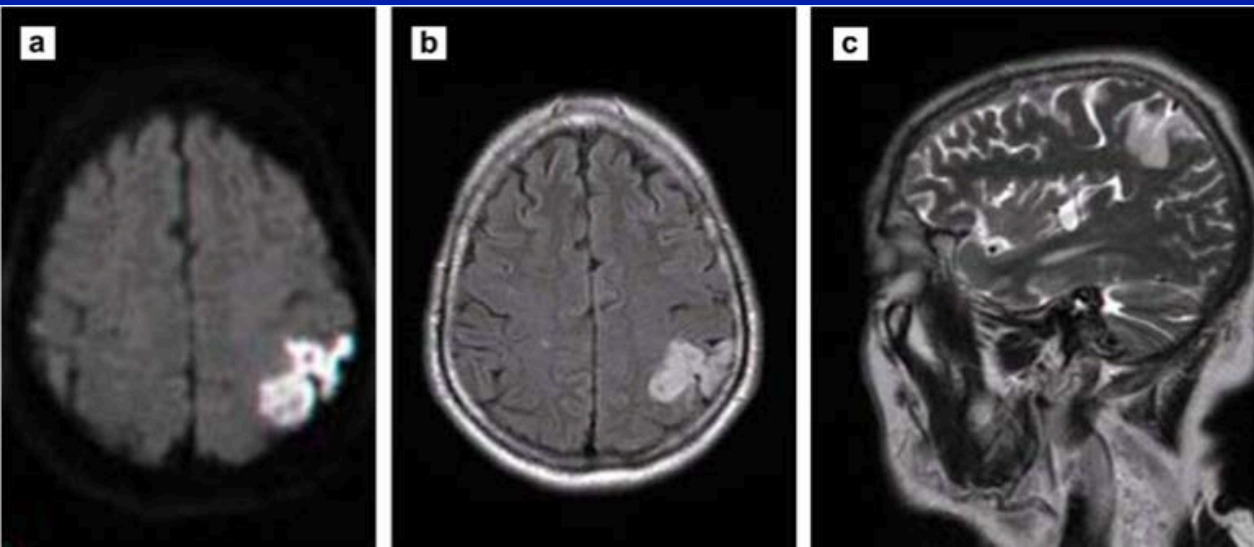
Table 3 – Arithmetic battery part 1: number comprehension and production

	AD	Controls
Matching written Arabic numbers to quantities	5/5	5/5
Comprehension of quantities	5/5	5/5
Serial order	2/2	2/2
Counting	5/5	5/5
Production (writing) of numbers	10/10	10/10
Dictation of arithmetical operators	4/4	4/4

Table 4 – Arithmetic battery parts 2–4: calculation

	AD	Controls
<i>Simple operations (one digit)</i>		
Addition	5/5	5/5
Subtraction	4/5	5/5
Multiplication	5/5	5/5
Division	5/5	5/5
<i>Complex operations (2 or 3 digits)</i>		
Addition	6/8 ^a	7.5/8
Subtraction	7/8	7.5/8
Multiplication	3/8 ^a	7.25/8
Division	6/8 ^a	7.75/8
<i>Decimals (e.g., 1.43 – .59=)</i>		
Addition	4/4	4/4
Subtraction	2/4 ^a	3.26/4
<i>Fractions (e.g., 1/2–1/4=)</i>		
Addition	5/5	4.75/5
Subtraction	1/5 ^a	4.75/5
Multiplication	5/5	4.5/5
Division	4/5	4.5/5

a Significant differences between AD and controls according to Crawford and Garthwaite (2004) and Crawford et al. (2004).



Size congruity task

2

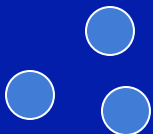
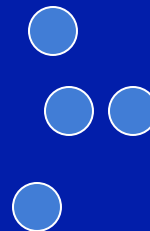
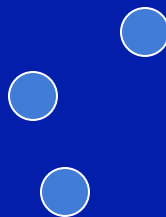
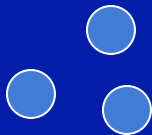
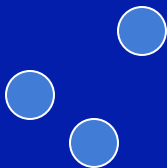
9

2

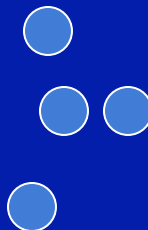
6

8

7



4



4

Magnitude comparison

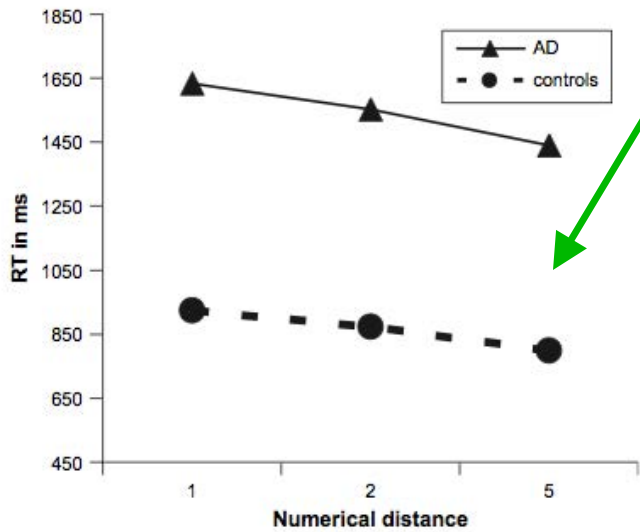


Fig. 3 – RT in the numerical task as a function of numerical distance.

Size congruity task : Distance x group interaction [F(1,31)1/47.57, MSE1/4146,491, p<.01]

In numerical congruity task, not in physical congruity task

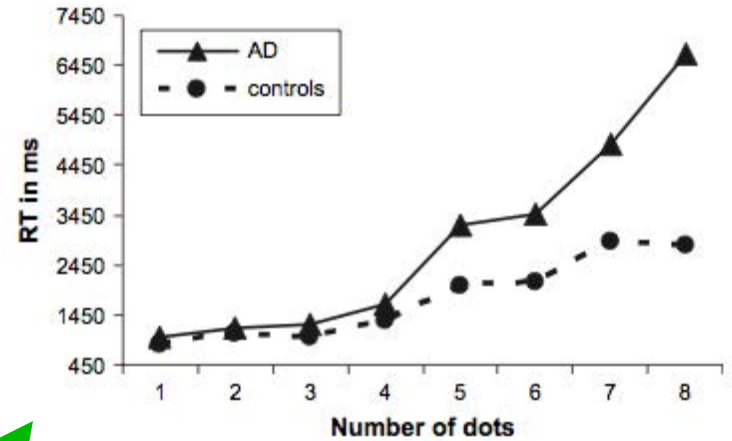


Fig. 5 – RT in the comparing dots to dots test as a function of the magnitude.

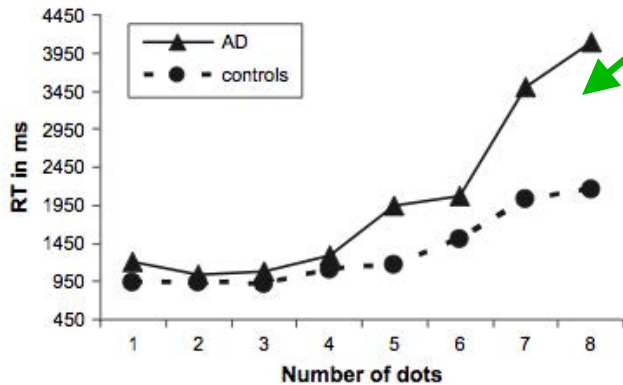


Fig. 4 – RT in the comparing digits to dots test as a function of the magnitude.

Slope differing in counting range (5–8) [F(1,31)1/47.93, MSE1/44,319,47,05]

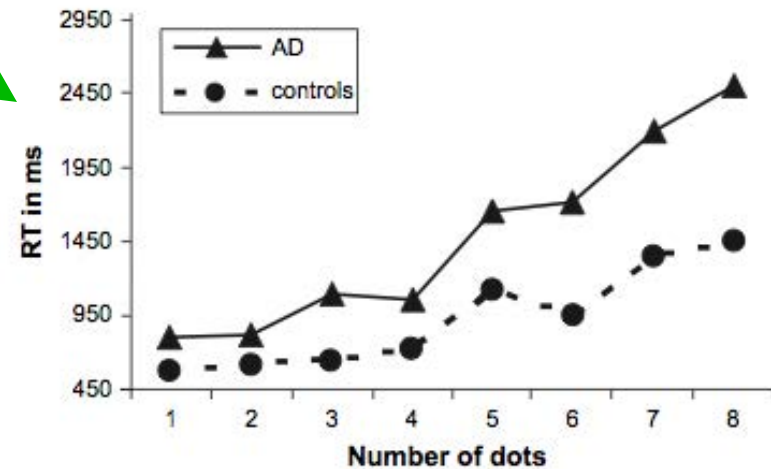


Fig. 6 – RT in the dot counting test as a function of the number of dots.

In basic numerical processing, AD exhibited: (1) a larger (or steeper) distance effect, (2) an abnormal size congruity indicated by a lack of facilitation, (3) a deficiency in counting, and (4) a deficiency in subitizing (i.e., a smaller than normal subitizing range). These observations, in conjunction with the fact that AD had a restricted injury to the superior part of the IPS with selective deficiency only in arithmetic, are important

Sillon intra-pariétal : un rôle
particulier pour la
représentation des quantités?

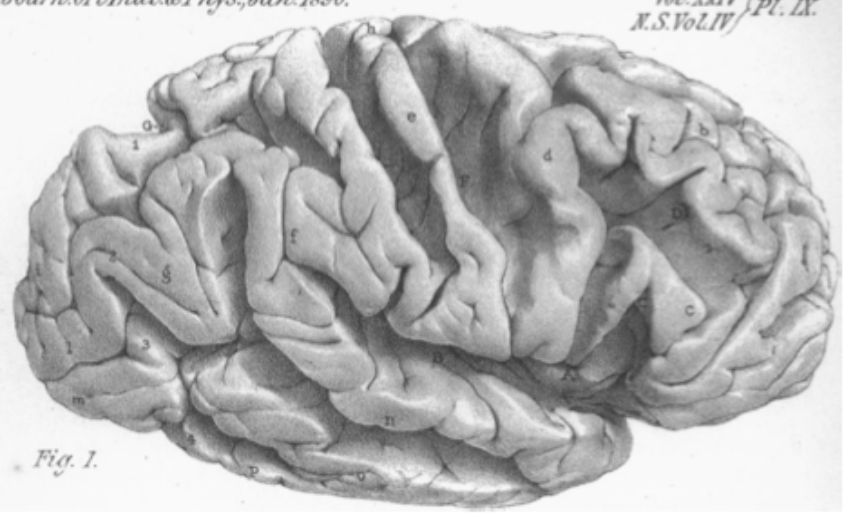


Fig. 1.

Journal of Anatomy and Physiology.

THE INTRAPARIETAL SULCUS OF THE BRAIN. By
D. J. CUNNINGHAM, M.D., *Professor of Anatomy, Trinity
College, Dublin.* (PLATE IX.)

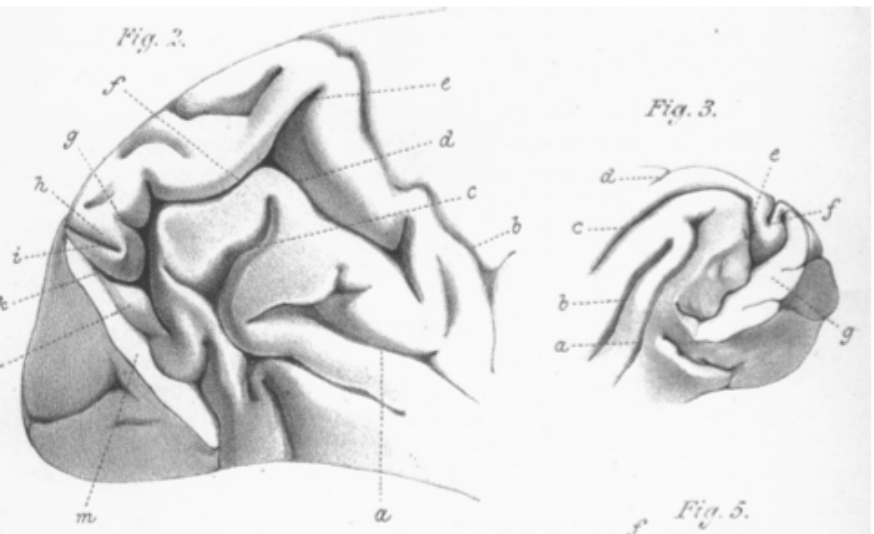


Fig. 2.

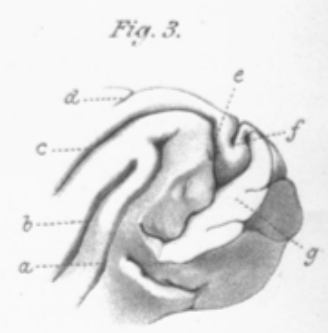


Fig. 3.

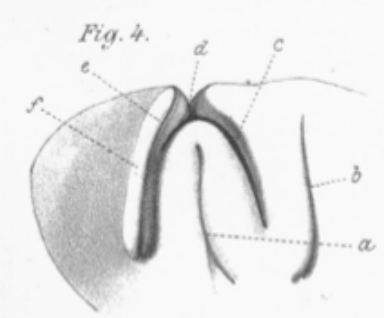


Fig. 4.

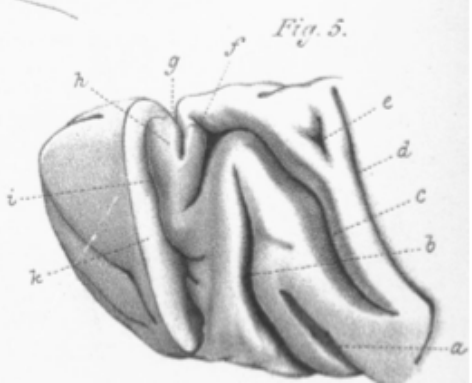
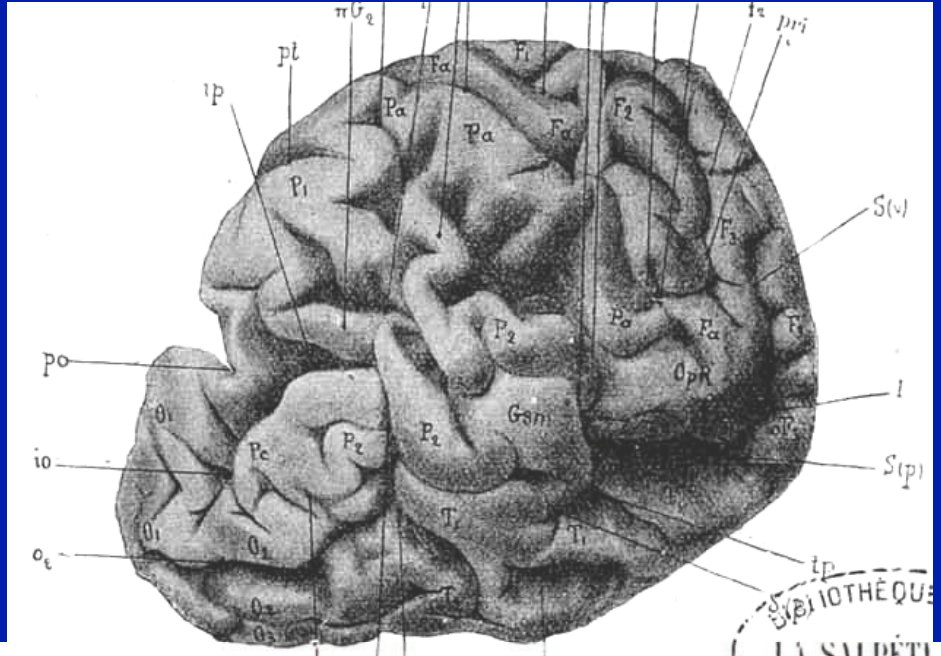


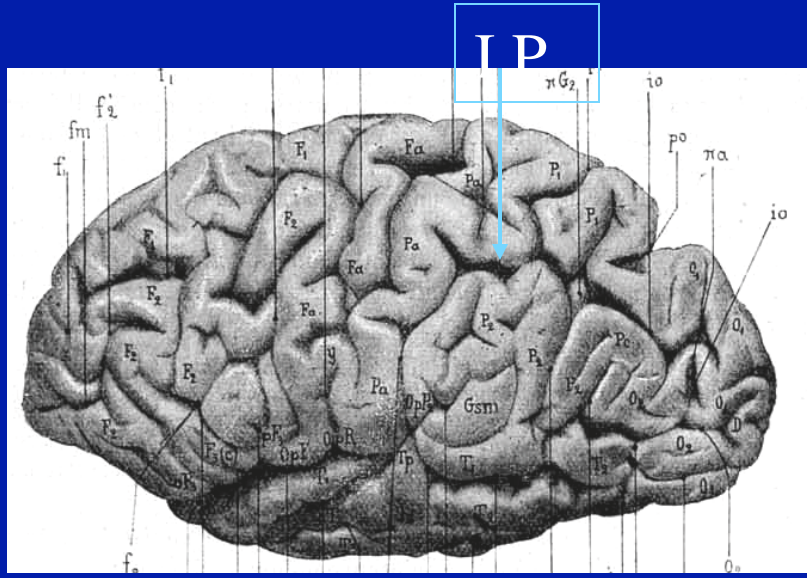
Fig. 5.

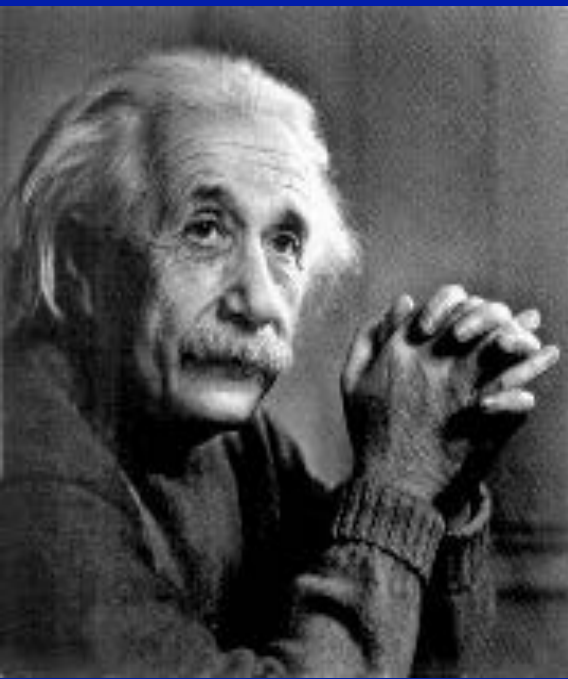
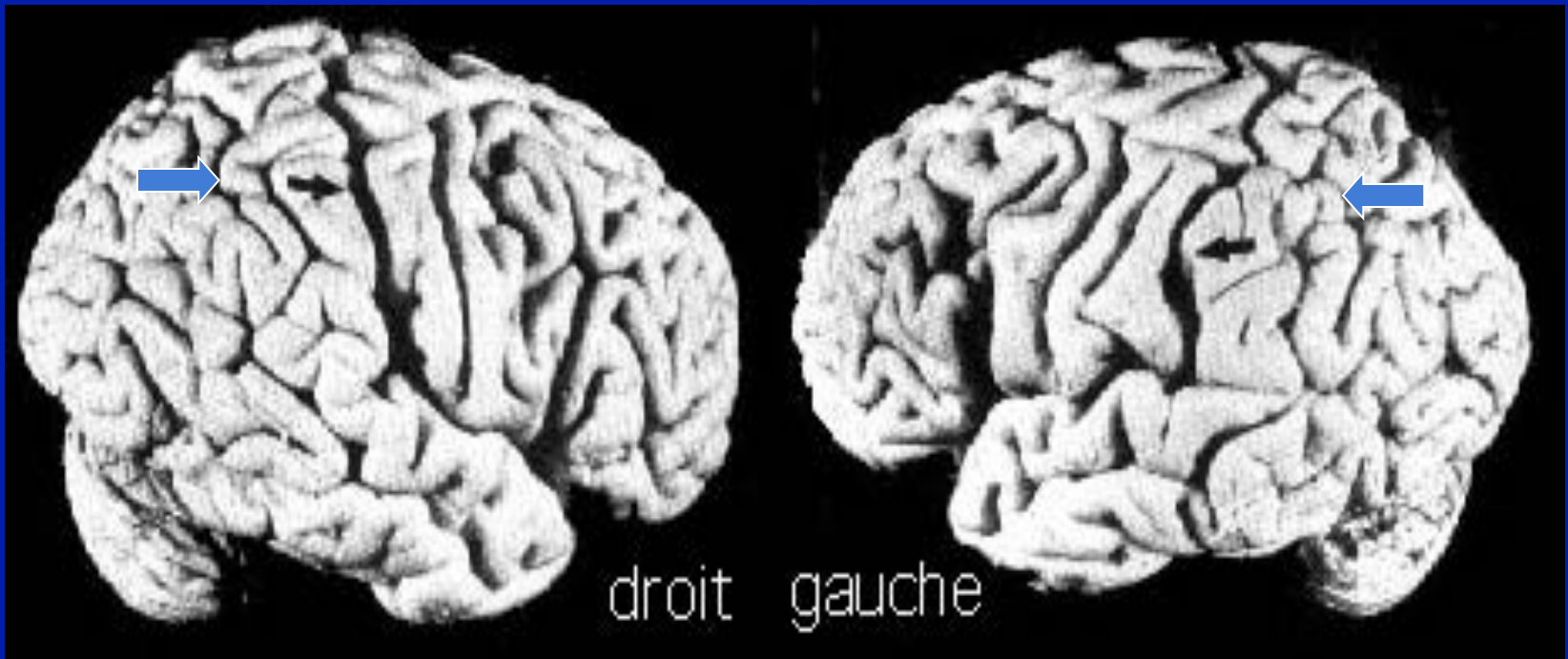




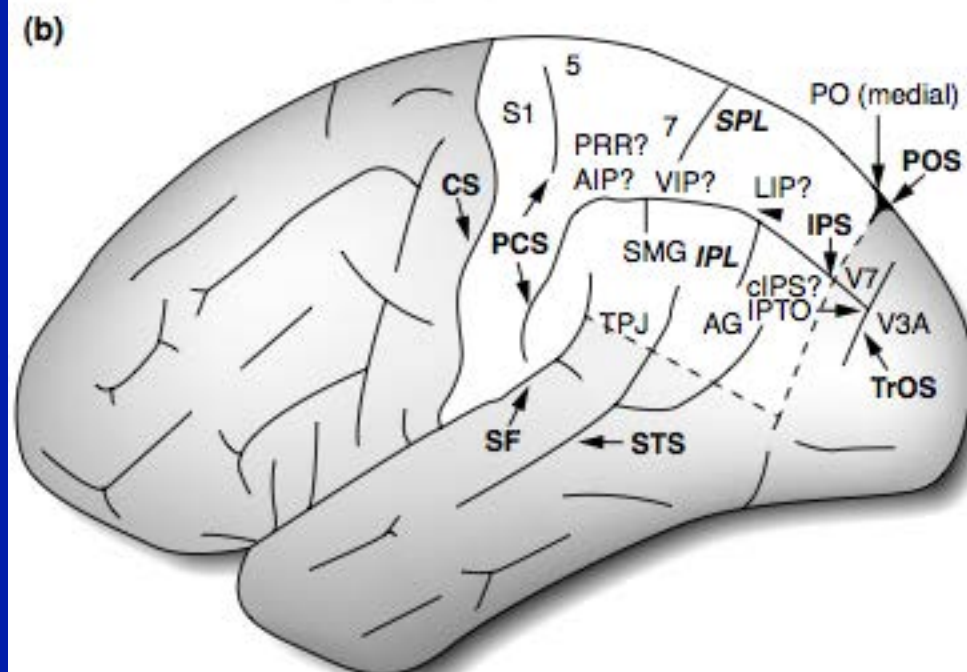
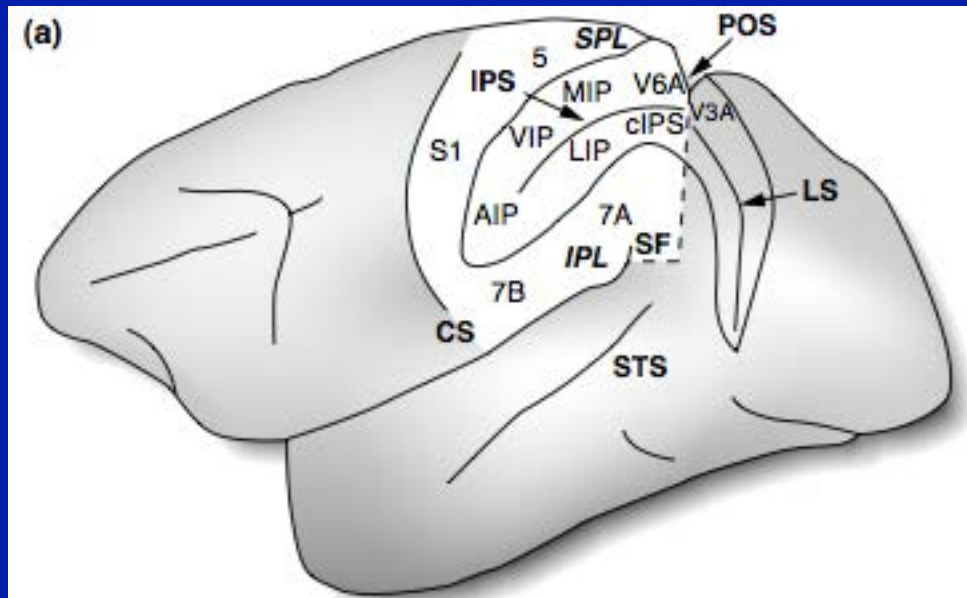
ANATOMIE - 23
 DES
CENTRES NERVEUX
 BIBLIOTHÈQUE DES
 LA SALPÊTRIÈRE
 INTERNES EN MÉDECINE
 J. DEJÉRINE
 PROFESSEUR AGRÉGÉ A LA FACULTÉ DE MÉDECINE DE PARIS

BIBLIOTHÈQUE
 LA SALPÊTRIÈRE





Einstein's brain : parietal "malformation"
(from Witelson et al., 1999)



Single-Neuron Arithmetic

Stanislas Dehaene

Numerical neurons. Cerebral networks that may underlie the sense of number in mammals (11). The brain areas that are activated when we compute a simple subtraction, such as $11 - 5$, may encompass areas homologous to those in the monkey and cat brain, where neurons tuned to a specific number have now been recorded.

Simon *et al.*,
2002



Human

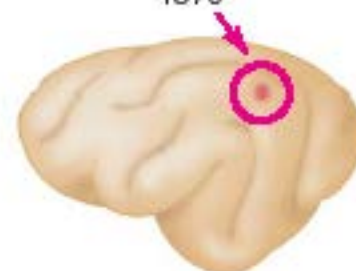
Nieder *et al.*,
2002

Sawamura *et al.*,
2002



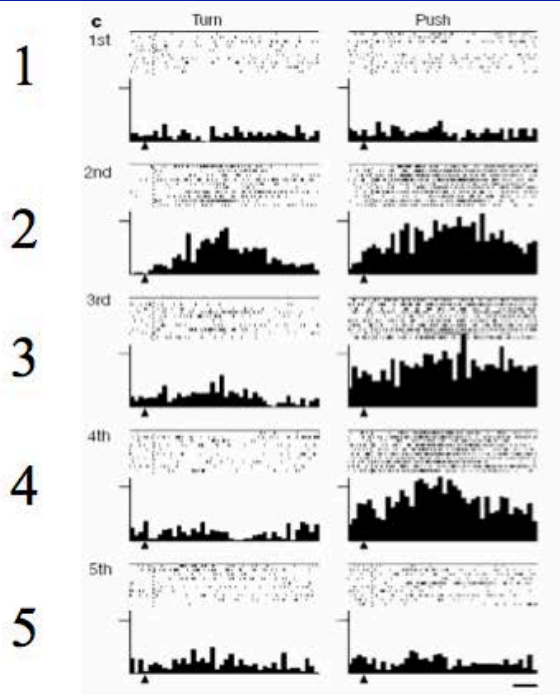
Monkey

Thompson *et al.*,
1970

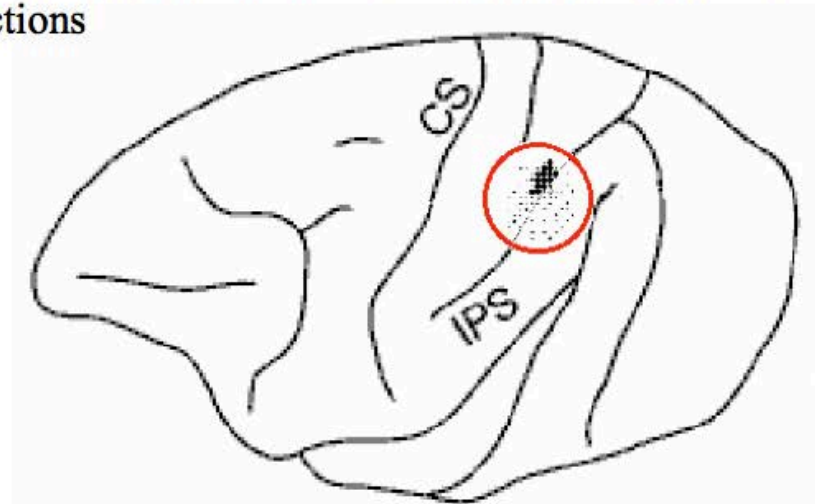


Cat

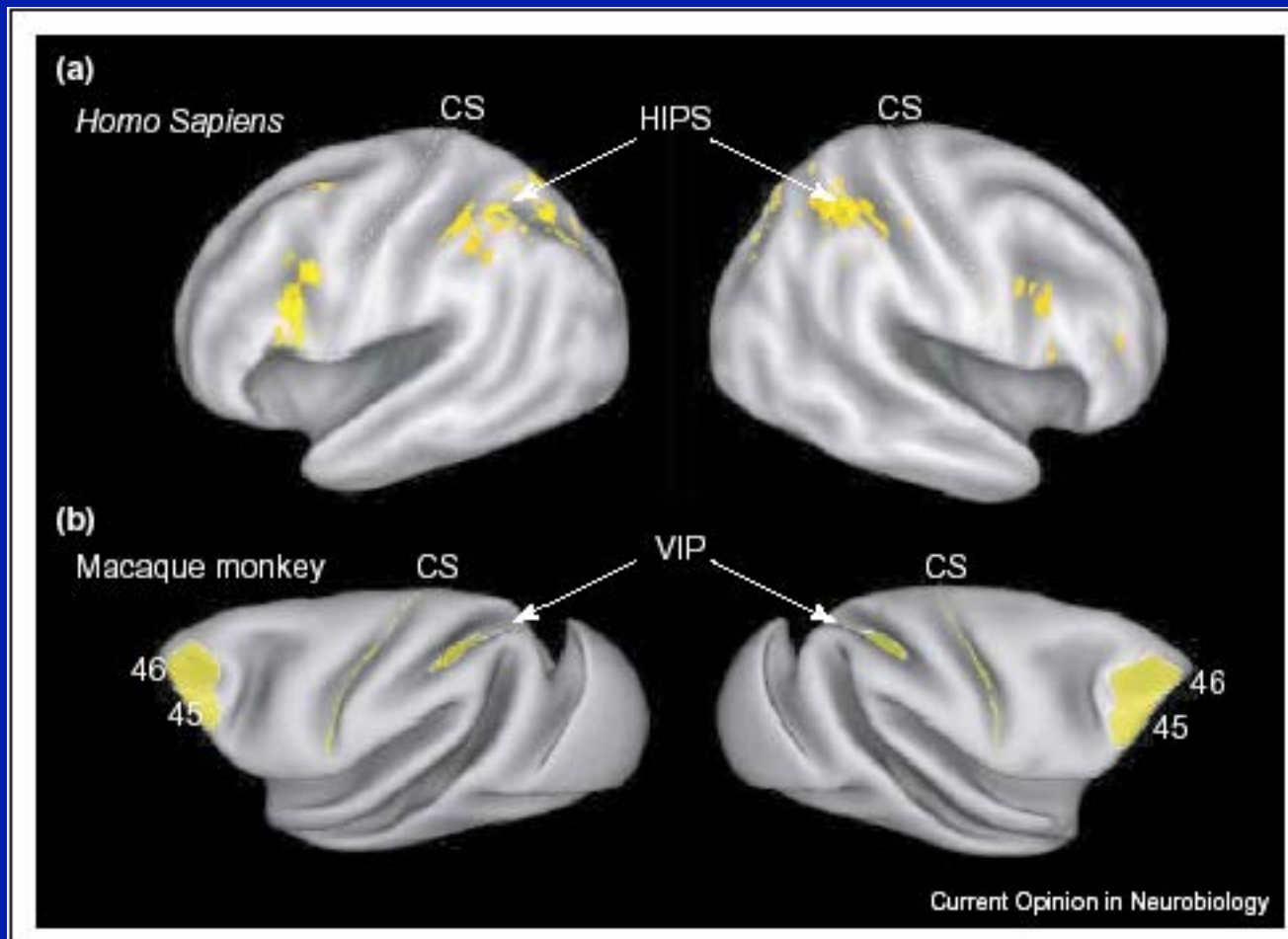
Codage du nombre d'actions dans le cortex pariétal du singe



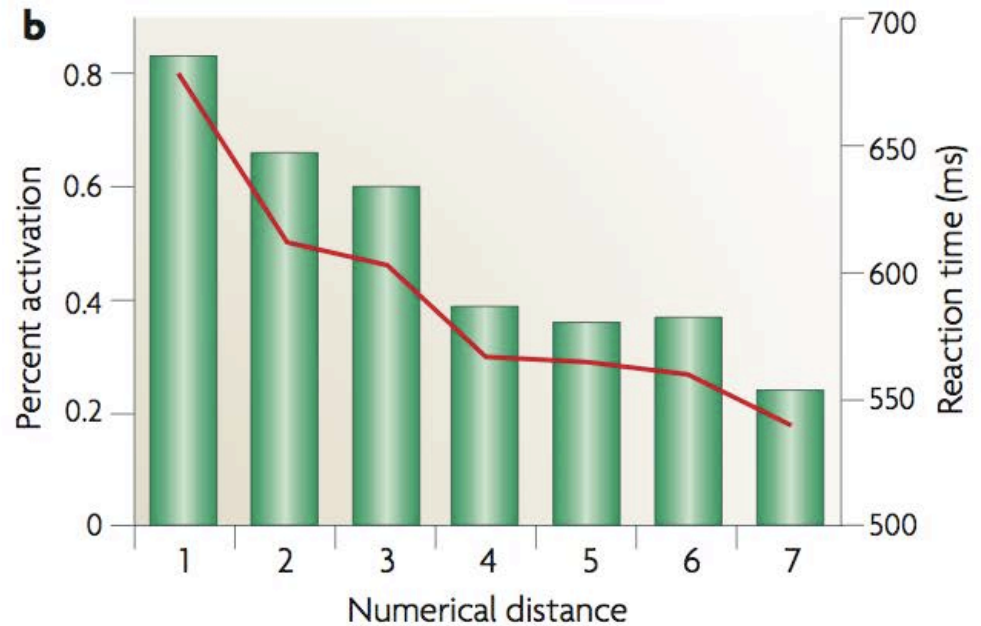
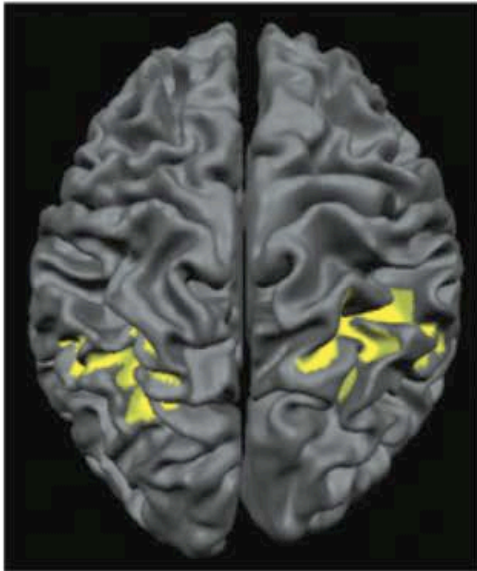
- Des neurones sensibles au nombre d'actions sont observés dans la partie antéro-latérale du sillon intrapariétale
- Cependant, ils répondent souvent différemment aux deux actions



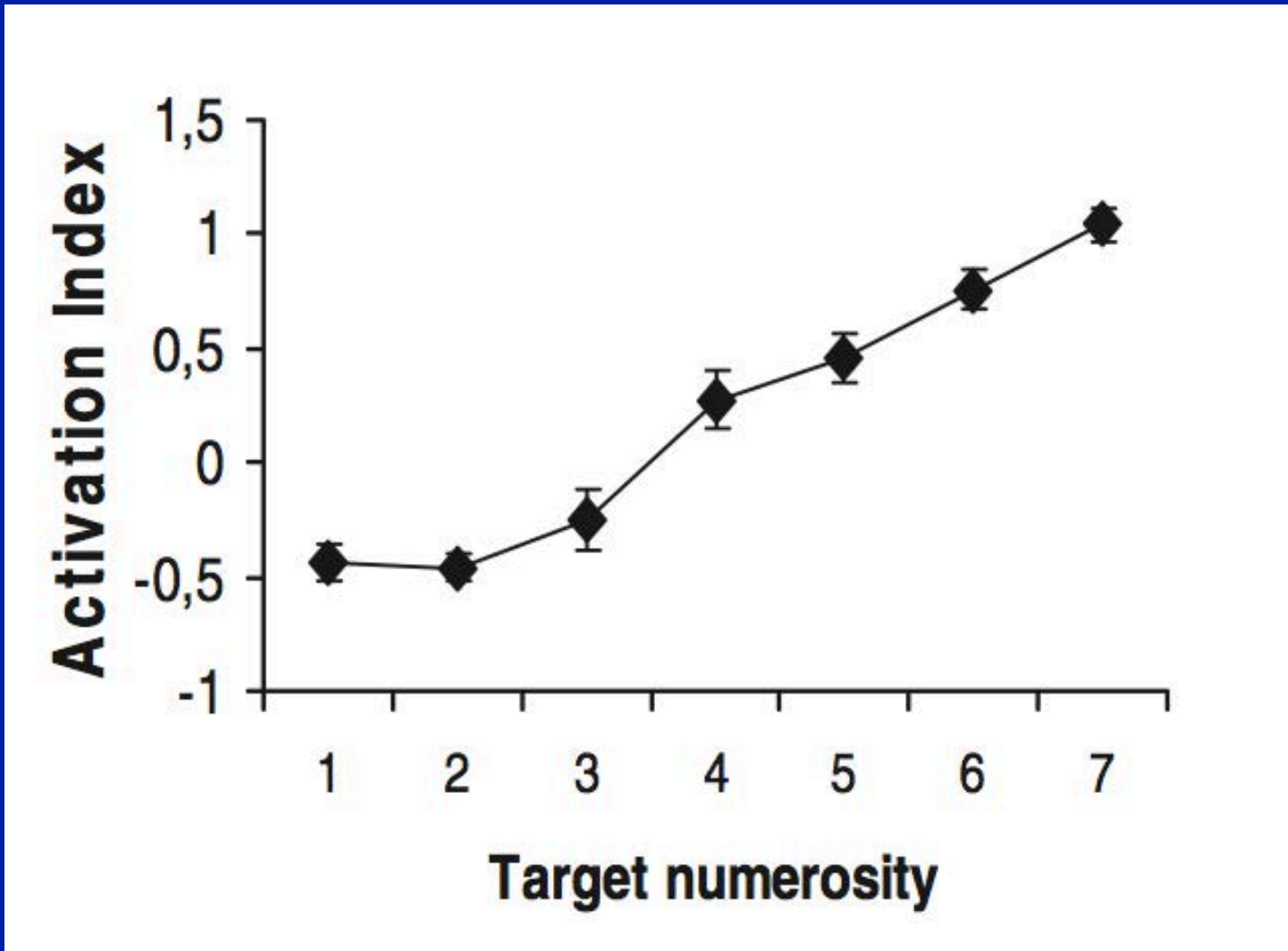
Traitement de la quantité chez les humains et primates non humains



"Il est bien possible que la région VIP du singe macaque soit le précurseur de la région hIPS activée pendant l'arithmétique mentale dans l'espèce humaine" (S. Dehaene)



le degré d'activation du sillon intrapariétal en IRMf dans une tâche de comparaison de deux numéros est une fonction inverse de la distance entre les deux nombres à comparer (Pinel et al., 2001)



degré d'activation de la région pariétale postérieure en IRMf selon la numérosité de la collection présentée. Alors que le degré d'activation est faible et constant pour les numérosités de 1 à 3, il augmente de façon proportionnelle au nombre d'items de 3 à 7, suggérant l'indépendance des mécanismes sous-jacents à la subitisation (reconnaissance immédiate pour les objets de 1 à 3 items) et au comptage (objets de 4 à 7 items).

Report

Virtual Dyscalculia Induced by Parietal-Lobe TMS Impairs Automatic Magnitude Processing

Roi Cohen Kadosh,^{1,2,*} Kathrin Cohen Kadosh,¹ Teresa Schuhmann,⁴ Amanda Kaas,^{4,5} Rainer Go Avishai Henik,¹ and Alexander T. Sack⁴

¹Department of Behavioral Sciences and Zlotowski Center for Neuroscience Ben-Gurion University of the Negev Beer-Sheva 84105 Israel

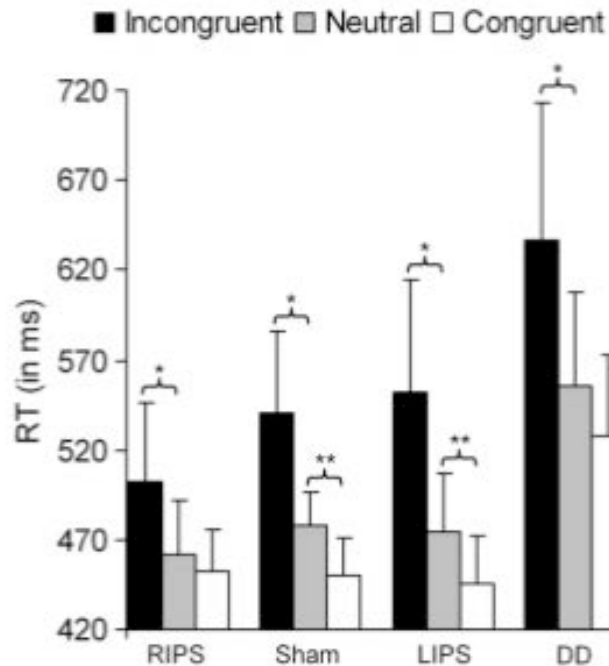
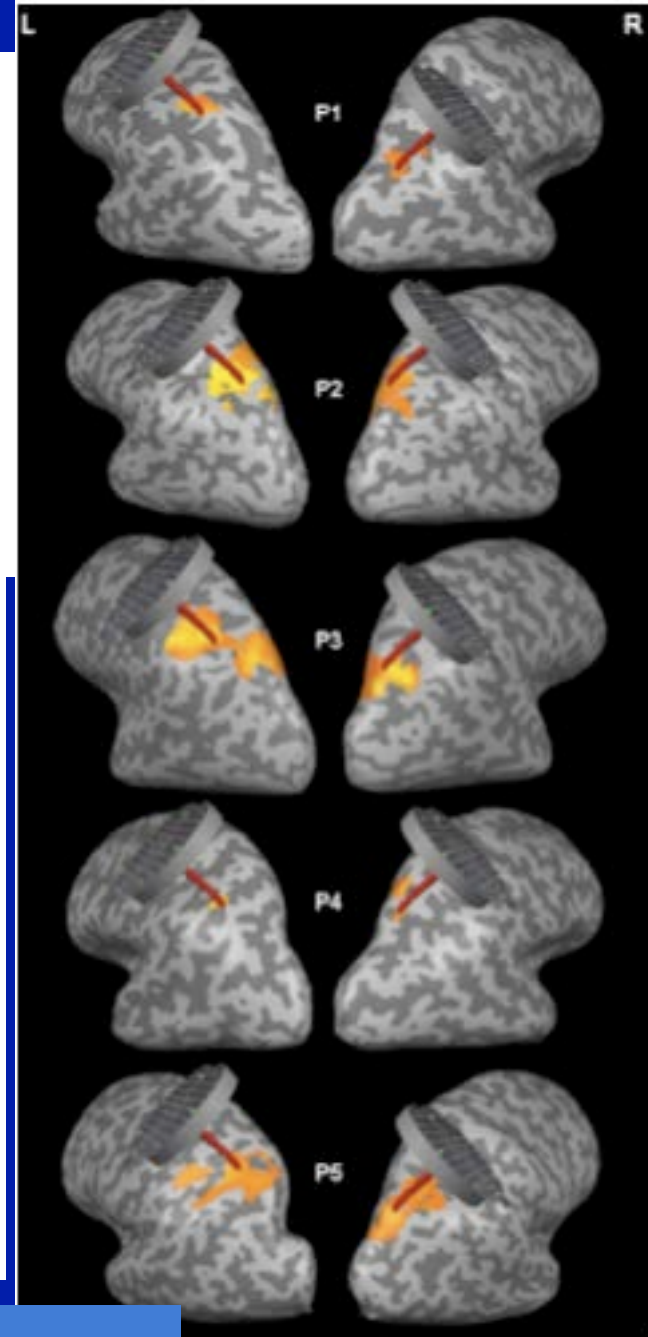


Figure 3. Reaction Times as a Function of Congruity for the Group with Developmental Dyscalculia and for TMS Stimulation Sites for the Nondyscalculic Group

Error bars depict one standard error of the mean. * < 0.05, ** < 0.005. The following abbreviations are used: developmental dyscalculia (DD), left IPS (LIPS), and right IPS (RIPS).



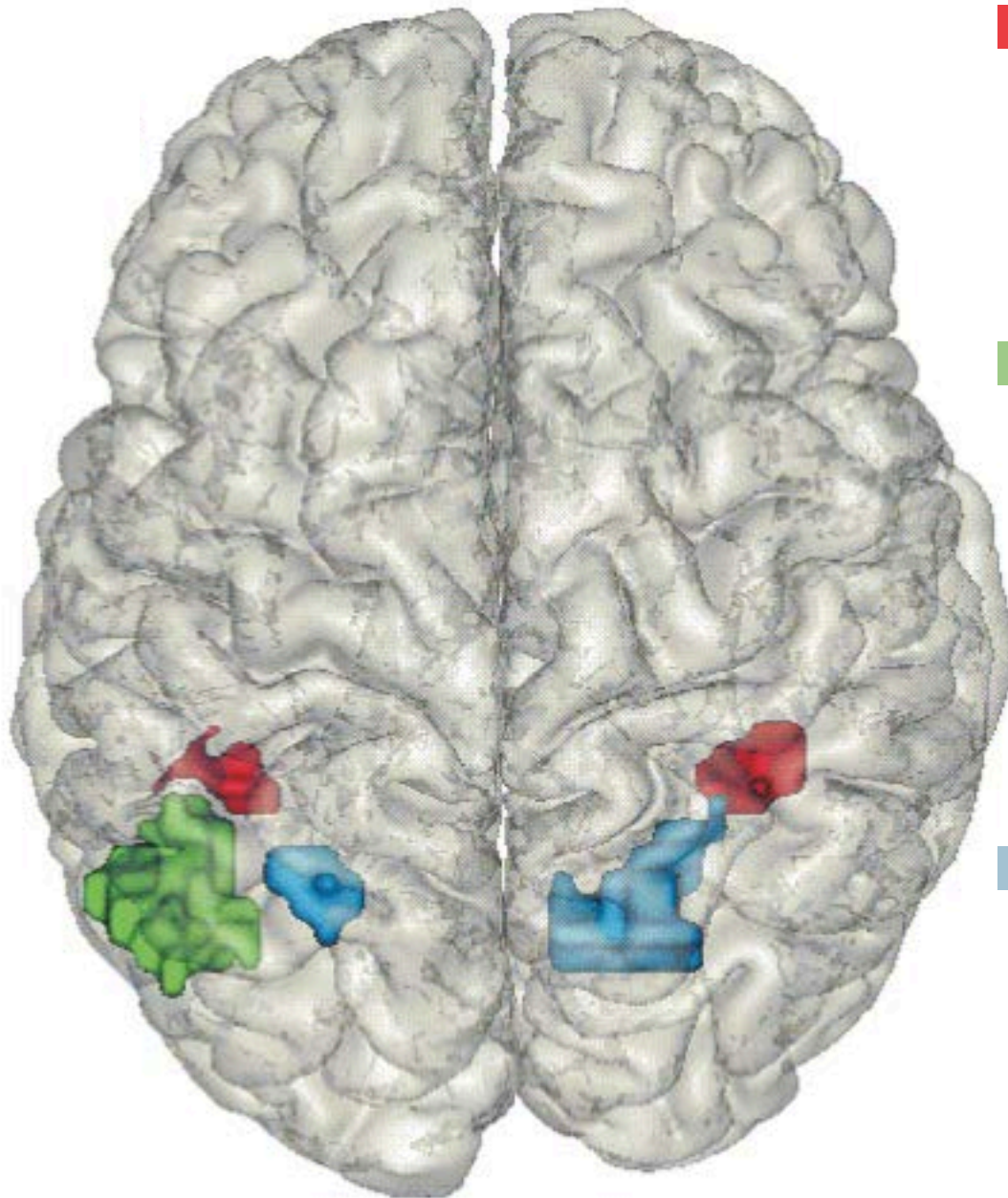
2 4 congruent

2 4 incongruent

2 4 Neutral : physical

2 2 Neutral : numerical

Inactivation pariétale droite : effet similaire aux dyscalculiques (interférence, mais pas de facilitation)



Segment horizontal du sillon intrapariétal bilatéral (HIPS)

- Activation dans toutes les tâches numériques - Effets de distance, de taille, d' amorçage... - Noyau de connaissances sur les quantités numériques?

Gyrus angulaire gauche (AG)

- Calculs mémorisés et dépendants d' un codage linguistique (calcul exact, multiplication...) - Egalement activé dans de nombreuses tâches verbales non- numériques - Codage verbal des faits arithmétiques?

Région pariétale supéro-postérieure bilatérale (PSPL)

- Activation dans certaines tâches: soustraction, approximation, effet de distance - Egalement activé lors de tâches d' attention visuo-spatiale - Orientation de l' attention sur la "ligne numérique mentale"?

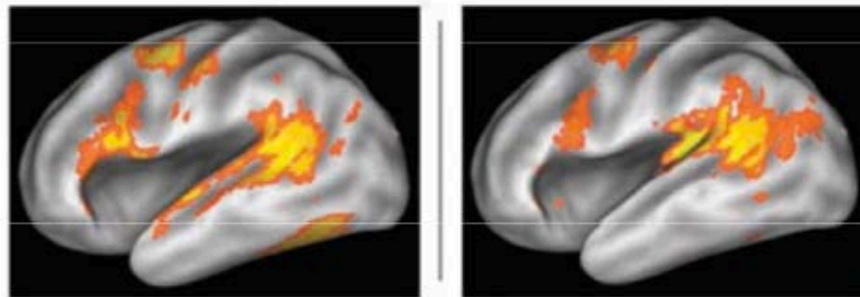
(Dehaene, Piazza, Pinel & Cohen 2003)

Language lateralization predicts hIPS lateralization during calculation

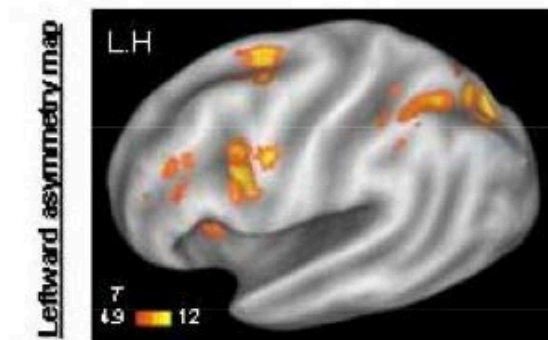
Pinel & Dehaene, *Beyond hemispheric dominance. J Cognitive Neuroscience* 2009

Database of 209 subjects, all scanned
at 3T with the same localizer

**Hemispheric asymmetries
in sentence reading and listening**



Hemispheric asymmetries in calculation



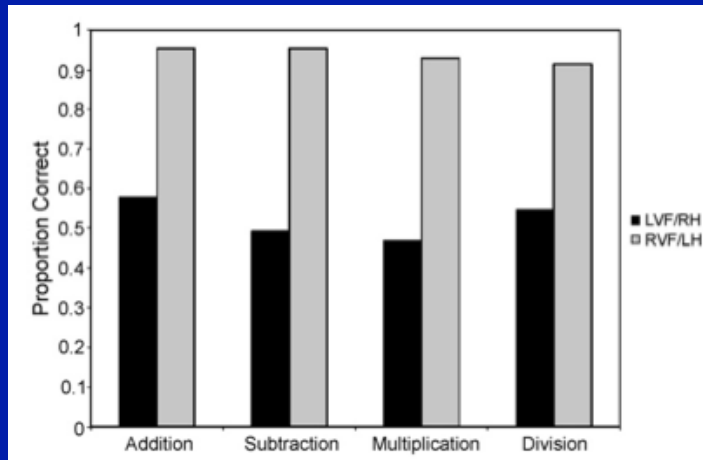
n

The calculating hemispheres: Studies of a split-brain patient

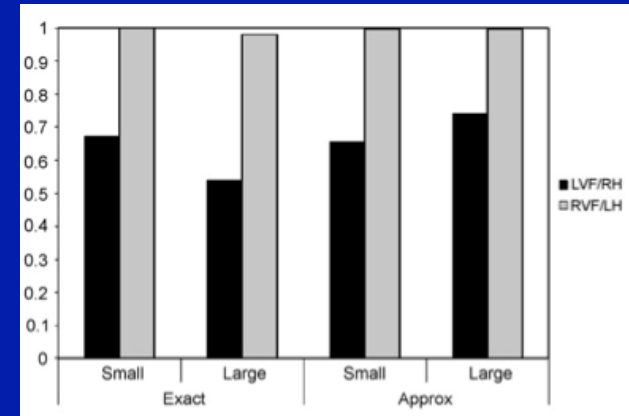
Margaret G. Funnell^{a,*}, Mary K. Colvin^a, Michael S. Gazzaniga^b

^a Center for Cognitive Neuroscience, Dartmouth College, 6207 Moore Hall, Hanover, NH 03755, United States

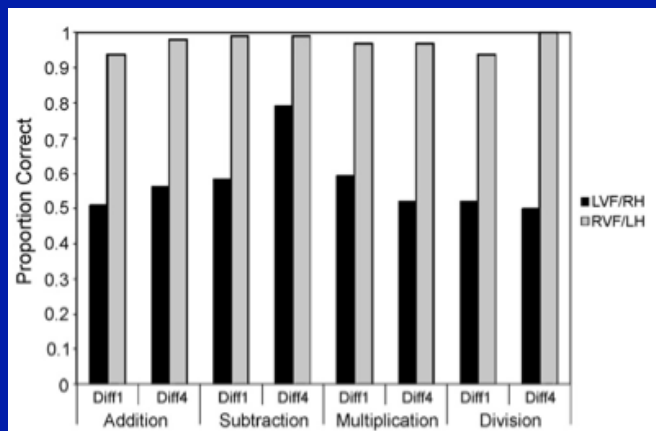
^b Department of Psychology, University of California, Santa Barbara, CA 93106, United States



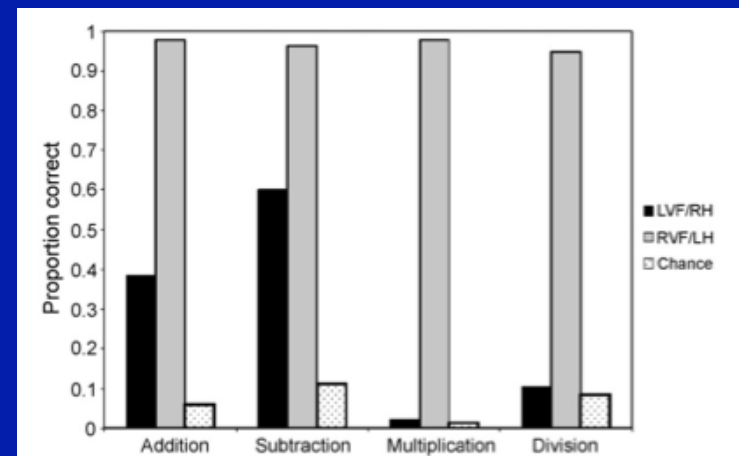
Vérification de solutions à des problèmes arithmétiques simples



Reconnaissance de solutions d'additions avec calcul exact ou approximatif



Reconnaissance de solutions pour des leures proches (1) ou éloignés (4)



Production écrite du résultat de la main ipsilatérale

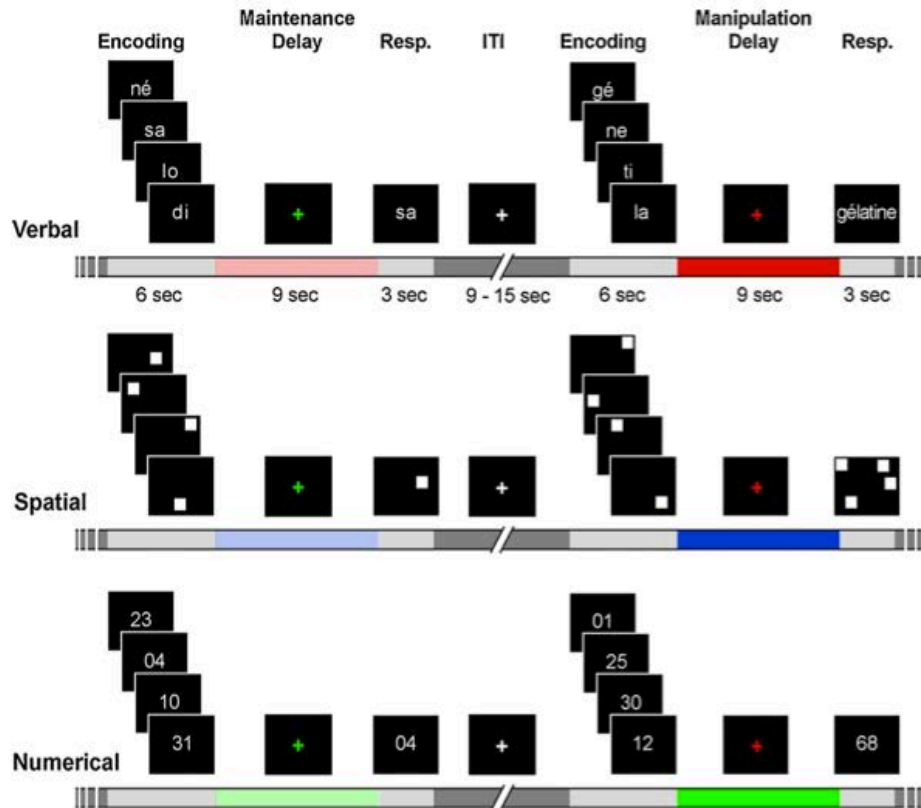
How verbal and spatial manipulation networks contribute to calculation: An fMRI study

Laure Zago*, Laurent Petit, Marie-Renée Turbelin, Frédéric Andersson, Mathieu Vigneau, Nathalie Tzourio-Mazoyer

CI-NAPS UMR 6232, CNRS, CEA, Université Caen Basse Normandie, Université Paris Descartes, France

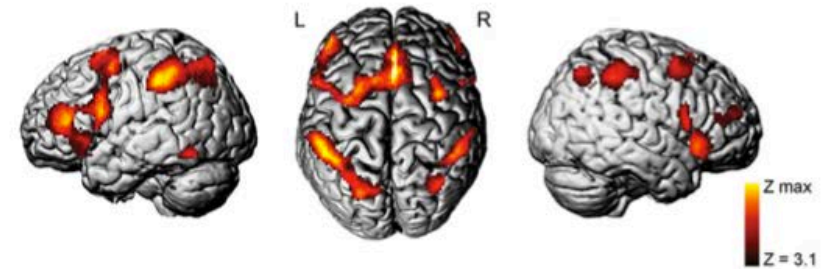
"calculation and spatial manipulation networks share common substrates, implemented in a right hemisphere fronto-parietal system underlying spatial attentional processes"

L. Zago et al. / Neuropsychologia 46 (2008) 2403–2414



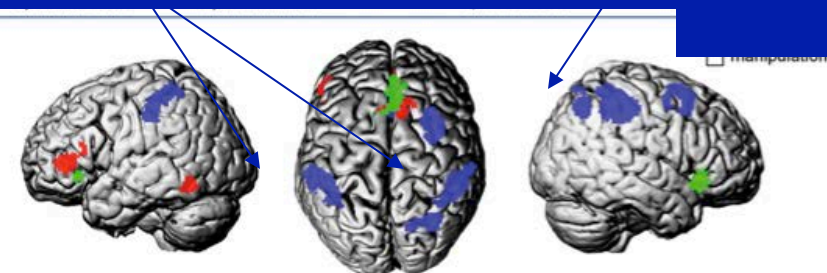
L. Zago et al. / Neuropsychologia 46 (2008) 2403–2414

Manipulation minus Maintenance of numbers

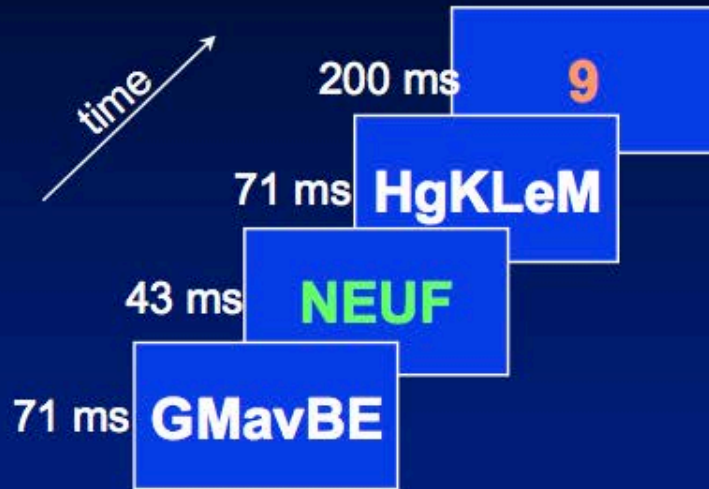


Overlapped activations between numbers and syllables (red), numbers and locations (blue)

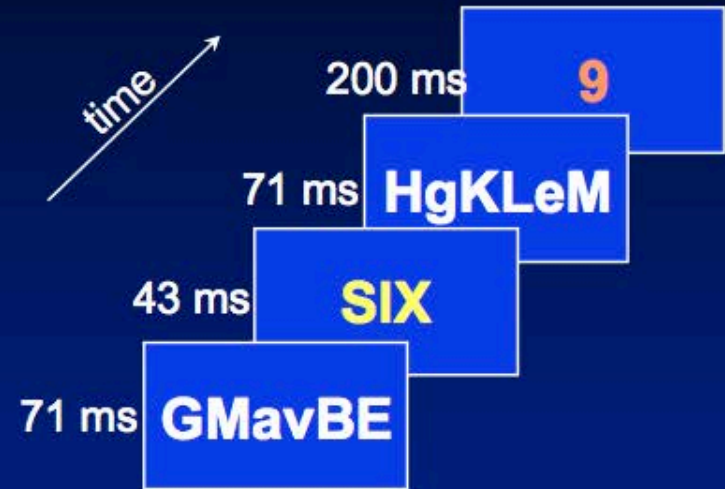
Activations communes nombres/localisations:
 Pariétal antérieur bilat gyrus angulaire droit



Le traitement inconscient des nombres



Même quantité

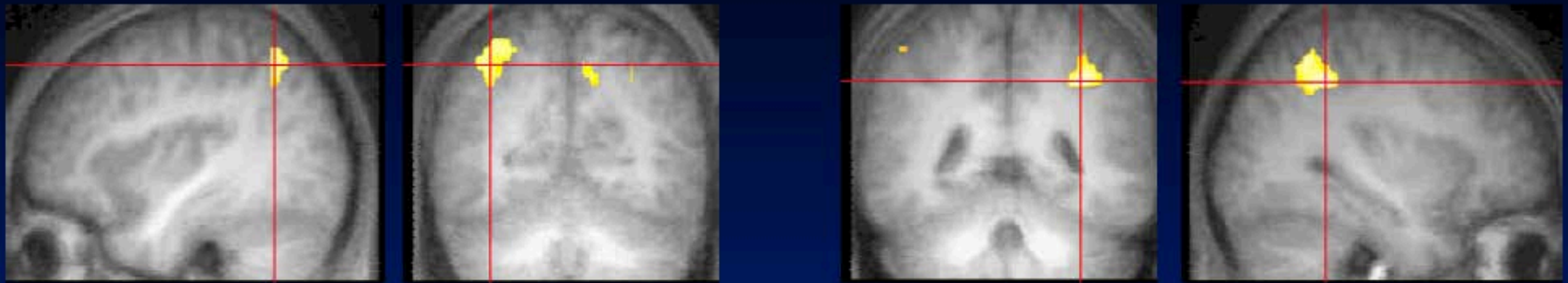


Deux quantités différentes

réponse de comparaison ralentie

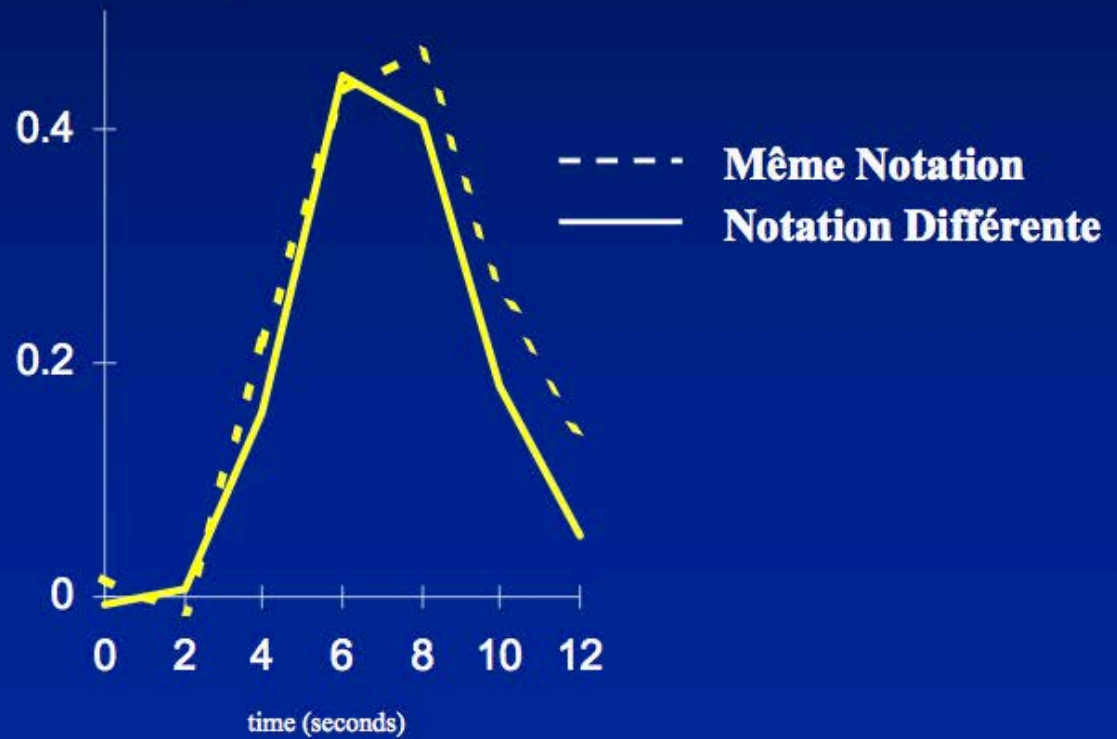
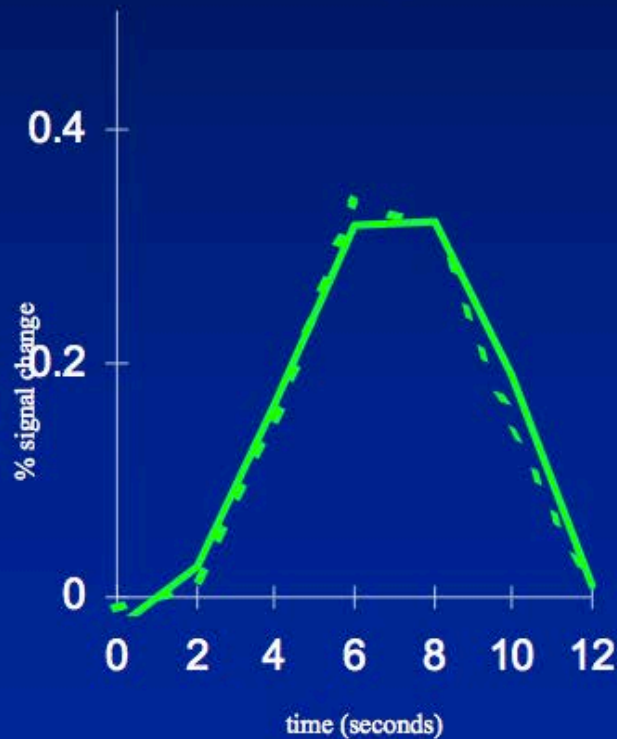
Traitement inconscient de la quantité

La région intrapariétale montre un effet d'amorçage inconscient



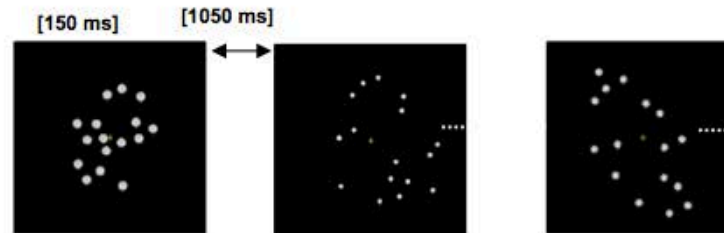
Même quantité

Deux quantités différentes

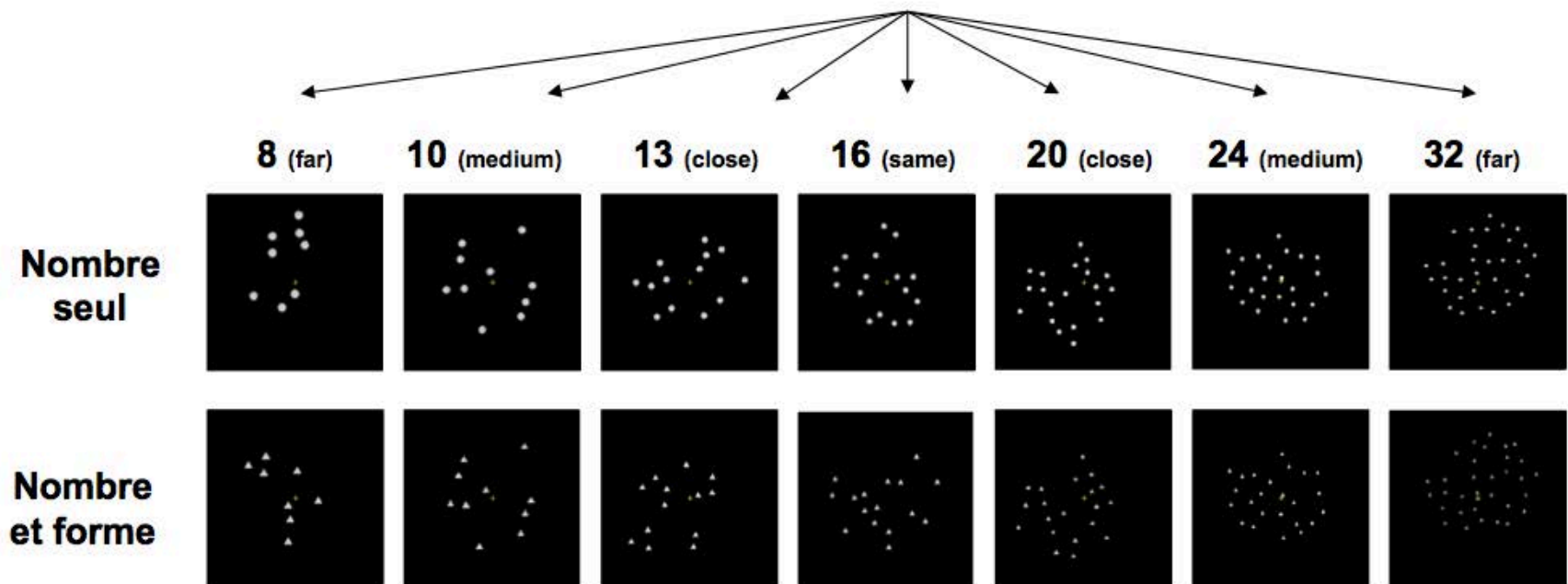


L'expérience d'adaptation numérique de Piazza et al.

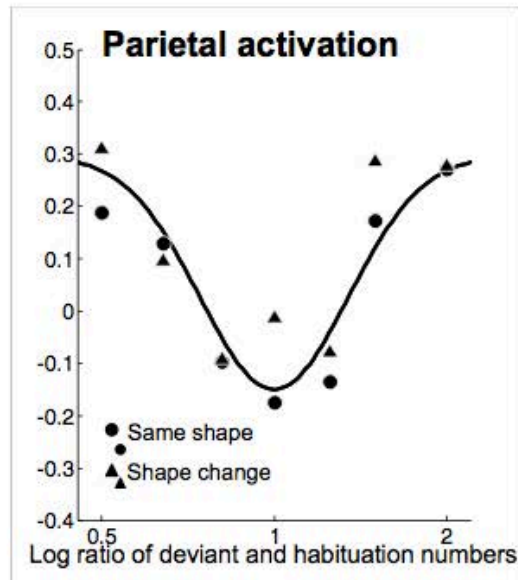
Adaptation à un nombre fixe (par exemple 16 points)



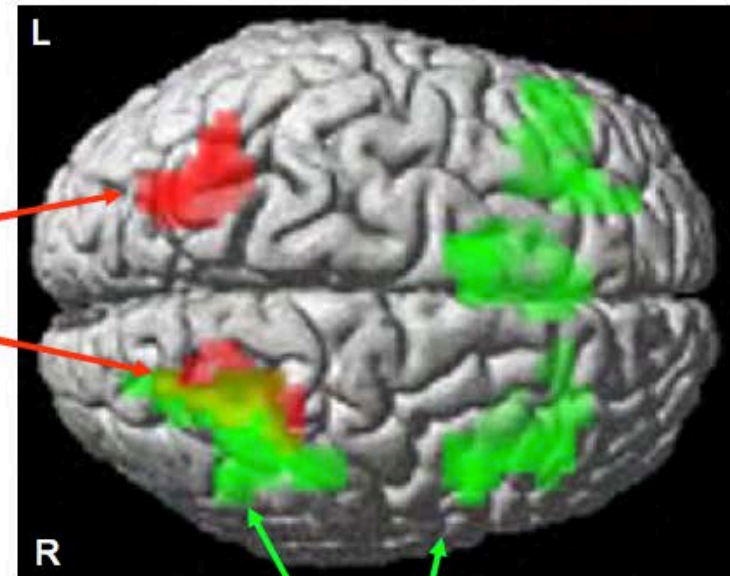
Stimuli de test



Adaptation numérique dans le segment horizontal du sillon intrapariétal (hIPS)

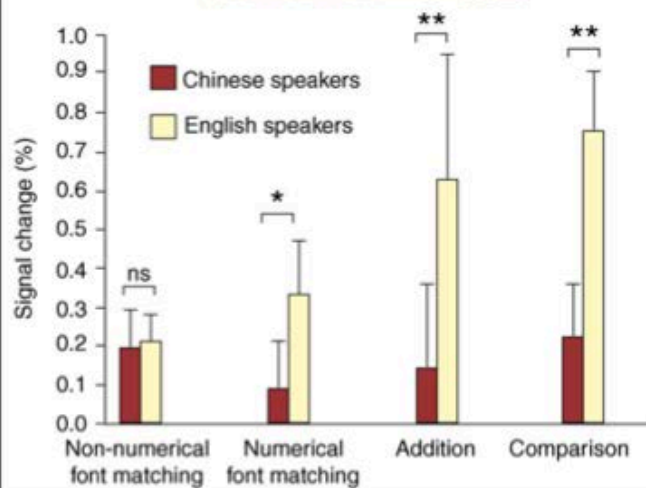
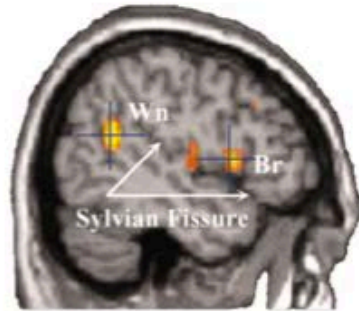


Régions qui
répondent à un
changement de
nombre

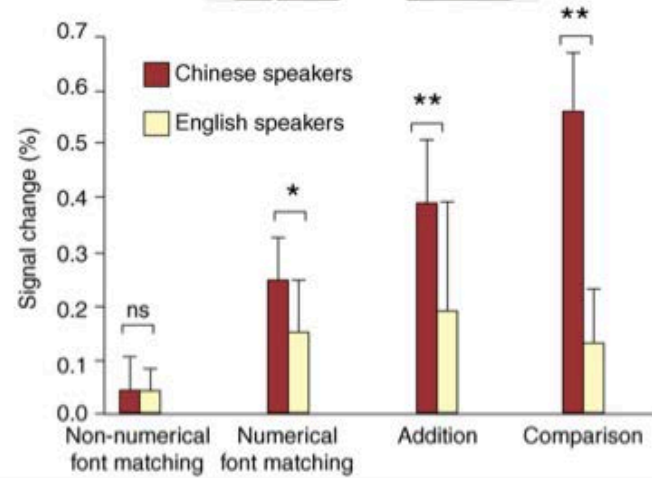
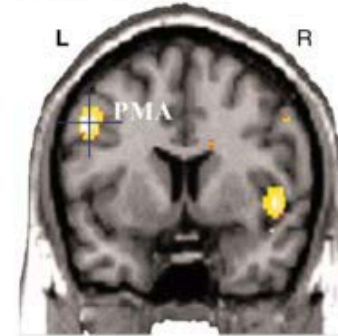


Régions qui
répondent à un
changement de
forme

(a) Greater activation in native English speakers than in native Chinese speakers



(b) Greater activation in native Chinese speakers than in native English speakers



Anglophones activent plus que Chinois les aires de Broca et Wernicke dans les 3 tâches numériques et non dans la tâche non numérique

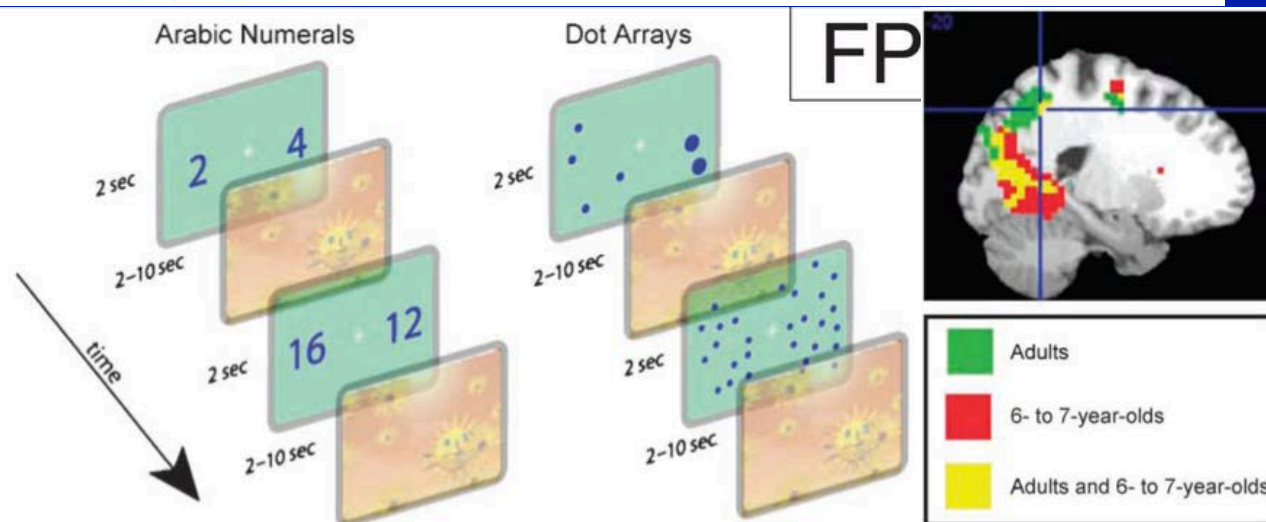
Chinois activent plus que Anglophones le cortex prémoteur dans les 3 tâches numériques et non dans la tâche non numérique

Comparaison adultes/enfants de 6-7 ans

The Neural Development of an Abstract Concept of Number

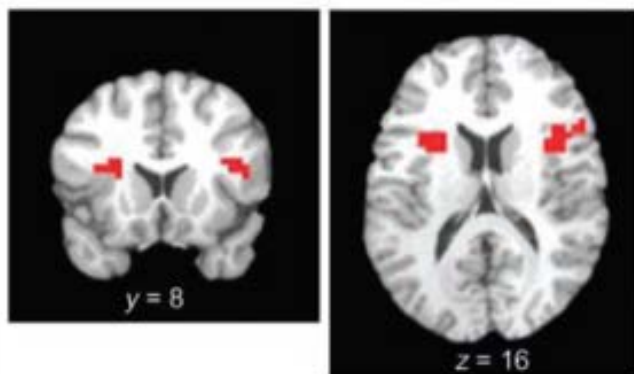
Jessica F. Cantlon^{1,2}, Melissa E. Libertus¹, Philippe Pinel^{3,4,5}, Stanislas Dehaene^{3,4,5,6}, Elizabeth M. Brannon¹, and Kevin A. Pelphrey⁷

¹ Duke University, Durham, NC

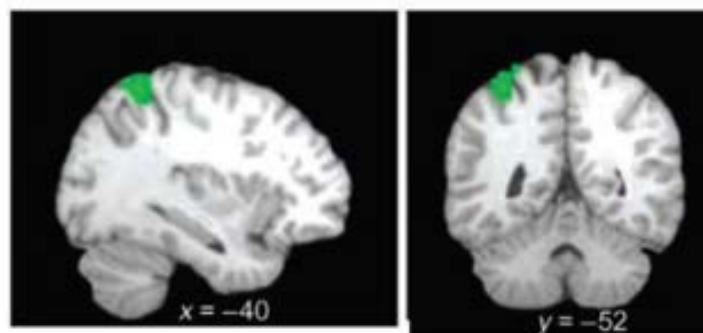


Analyse de conjonction des deux conditions

Children > Adults



Adults > Children



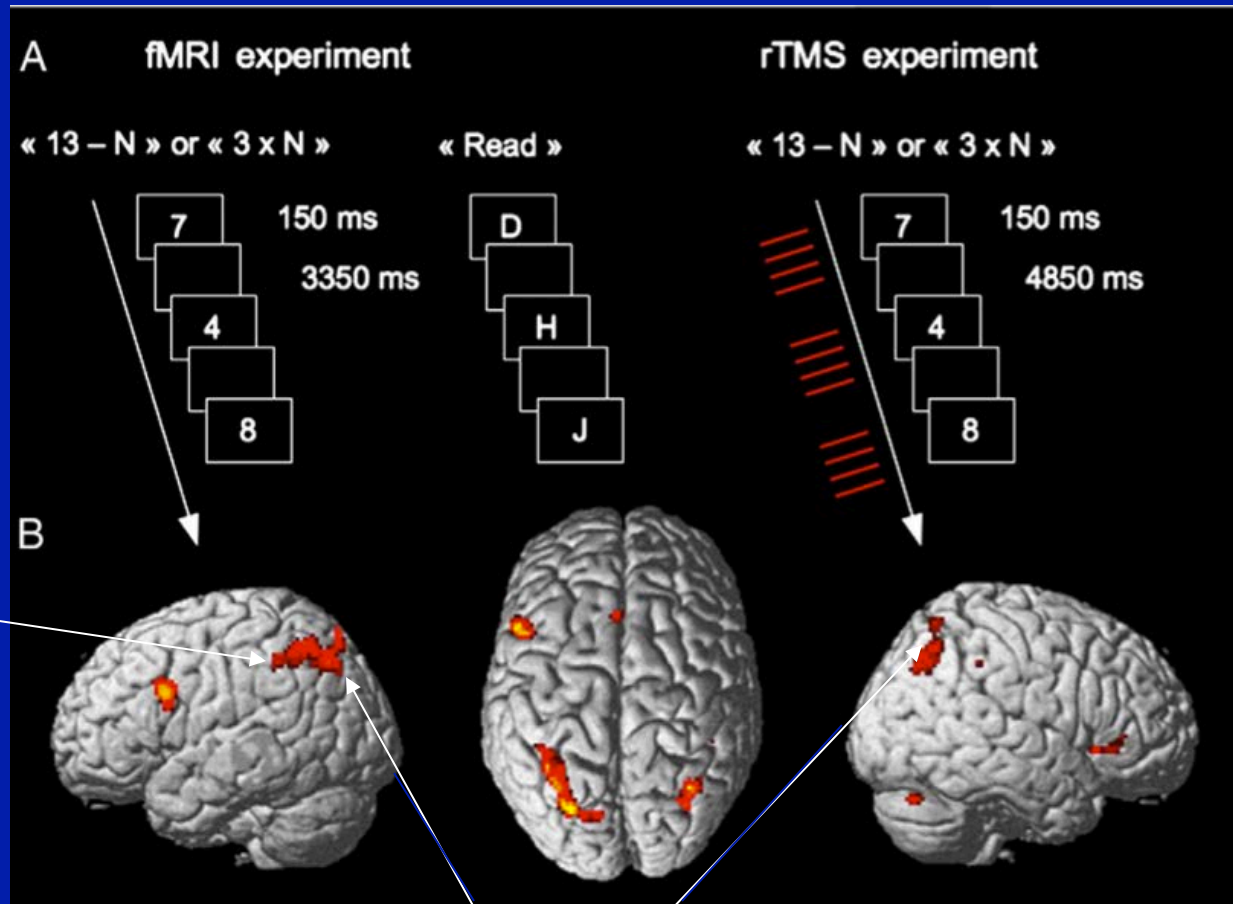
"a core neural system integrates notation-independent numerical representations throughout development but, early in development, higher-order brain mechanisms mediate this process."

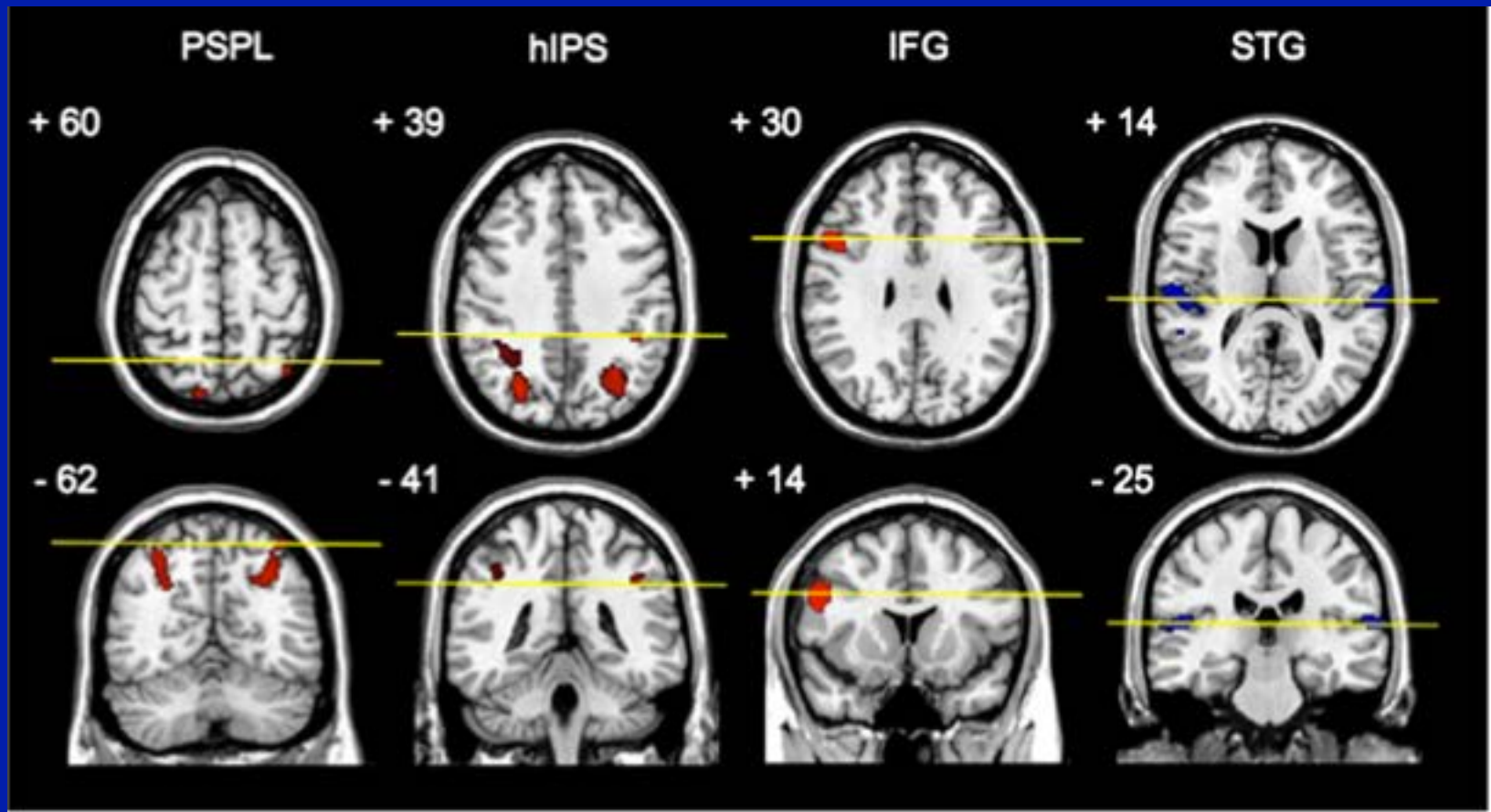
Role of distinct parietal areas in arithmetic: An fMRI-guided TMS study

Michael Andres^{a,b,*}, Barbara Pelgrims^b, Nicolas Michaux^a, Etienne Olivier^b, Mauro Pesenti^{a,b}

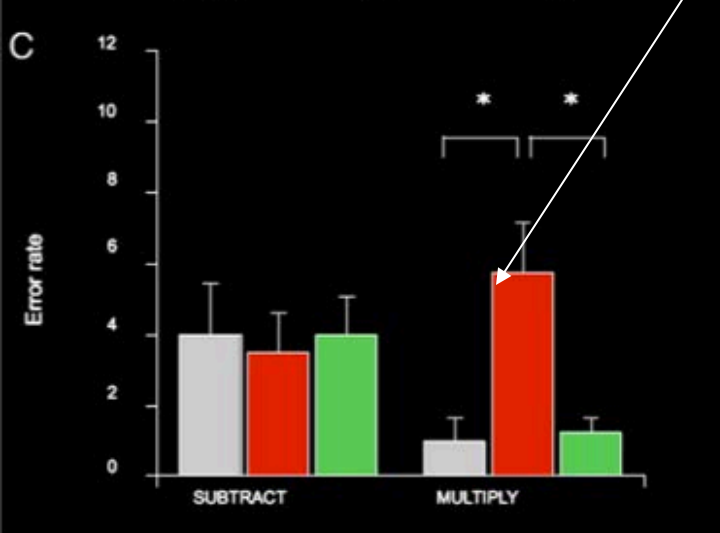
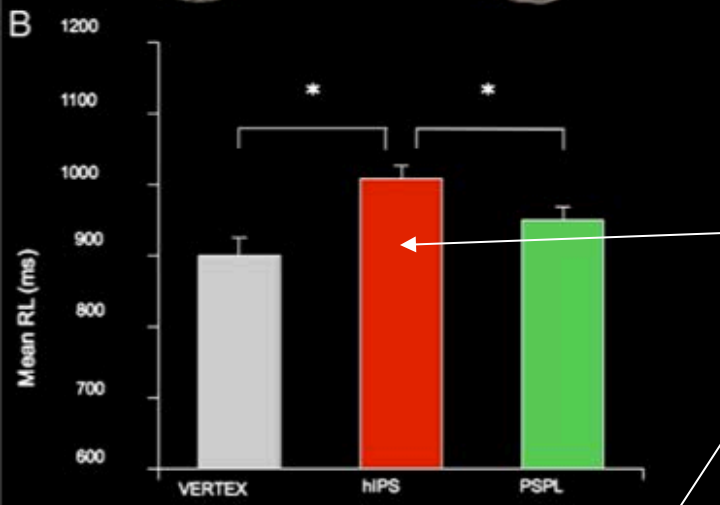
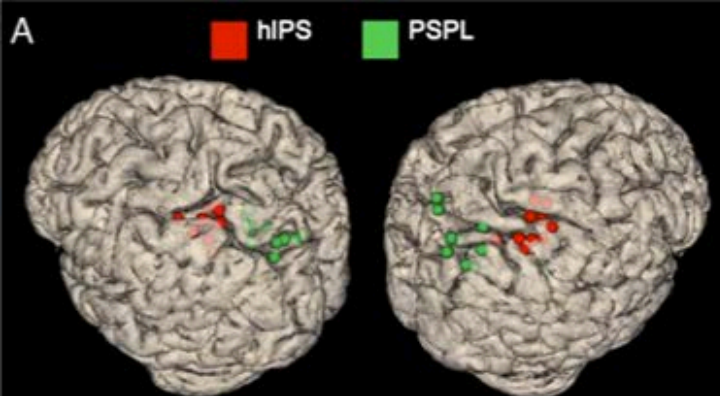
^a Institut de Recherche en Sciences Psychologiques, Université catholique de Louvain, Place Cardinal Mercier 10, 1348 Louvain-la-Neuve, Belgium

^b Institute of Neuroscience, Université catholique de Louvain, Avenue Hippocrate 54, 1200 Brussels, Belgium





Axial and coronal views of the brain regions showing increased activity during mental arithmetic. In each column, the yellow line crossing the axial view indicates the plane corresponding to the coronal view below and vice versa. Red clusters represent the parietal and frontal areas involved in subtraction and multiplication. The bilateral posterior superior parietal lobe (PSPL), the horizontal segment of the left intraparietal sulcus (hIPS) and the left inferior frontal gyrus (IFG) survived a corrected threshold of $p < 0.05$ in a conjunction analysis ($k=150$). Voxels showing increased activity during both arithmetic operations were also found in the right hIPS but only at an uncorrected threshold of $p < 0.001$. Blue clusters include perisylvian areas of the superior (STG) and middle temporal lobe showing more activity during multiplication than subtraction (corrected $p < 0.05$, $k=150$). No brain region was more activated during subtraction than multiplication



TMS experiment. (A) The stimulation sites of each participant are represented on two lateral views of a glass brain. Spheres are centred on the normalized MNI coordinates of individual stimulation points in the hIPS (red) and PSPL (green). (B) Mean Response Latencies (RL) as a function of the TMS site. (C) Mean error rate as a function of the arithmetic task and the TMS site. Error bars show within-subject corrected standard errors (Loftus and Masson, 1994) and asterisks signal significant differences between conditions (* $p < 0.05$ corrected for multiple comparisons).

Increased latencies from hIPS virtual lesion

Increased error rates for multiplication (not subtraction)

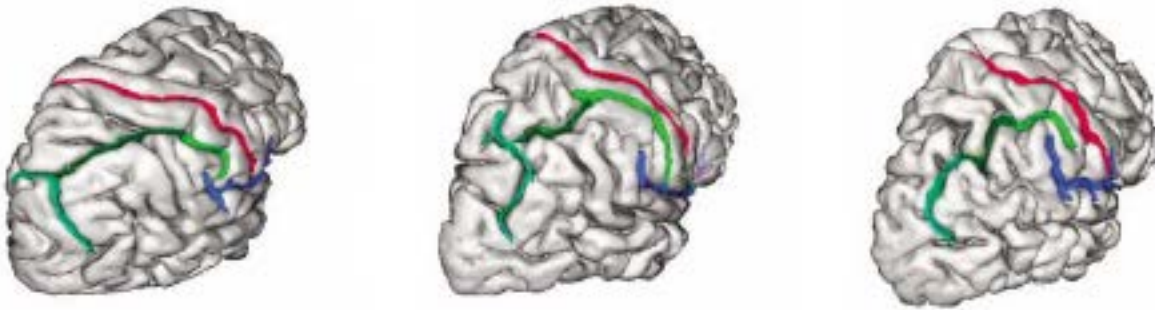
Using neuronavigated TMS, we evidenced for the first time that the integrity of the hIPS is required to perform arithmetic operations. Moreover, we showed that the hIPS contributes to the solving of both subtraction and multiplication problems, in contrast with the view that the brain networks underlying these operations are entirely separated. Our results also suggest that the PSPL underlies secondary processes which are not crucial to solve basic arithmetic problems.

Andres et al. (2011)

conclusions

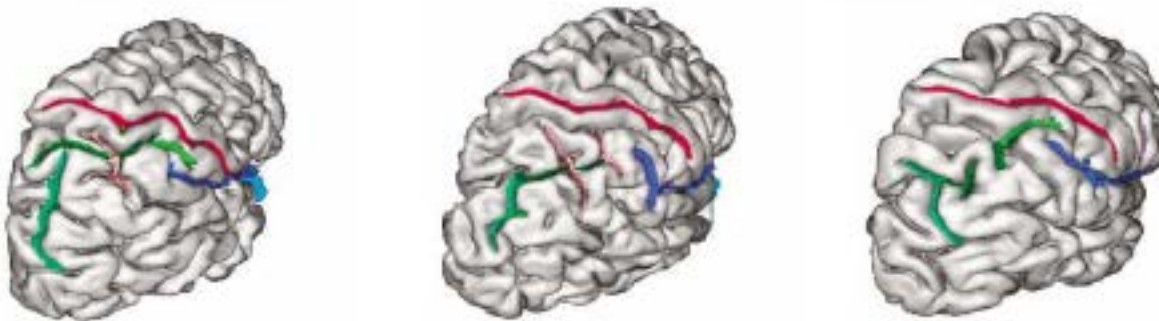
- Not only left, but also right hIPS virtual lesion (TMS) impairs calculation suggesting that the two homologue areas play complementary roles
- Contrary to expected, hIPS virtual lesions impaired both subtraction AND multiplication
- One possibility is that hIPS contributes to guide memory retrieval of arithmetic results in remote areas by determining the most plausible answer with respect to the magnitude of the numbers.
- the initial function of the PSPL in orienting attention could be "recycled" to perform attention shifts towards the left or right side of a mental numerical continuum, providing the intuition of removing or adding quantities
- The PSPL activation may be reminiscent of a specific stage in the development where visuospatial processes offer a start-up tool to represent intuitively addition and subtraction operations : once exact arithmetic abilities have been acquired, this approximate system is no longer essential for solving arithmetic problems, being limited to the monitoring of calculation procedures through estimation

Normal variability of the right IPS in three controls



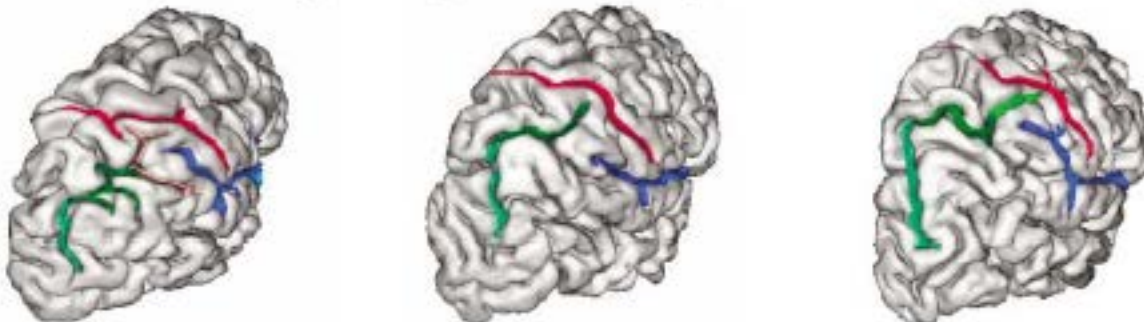
Témoins variations normales IPS

Unusual interruption of the horizontal portion of the right IPS in three TS subjects



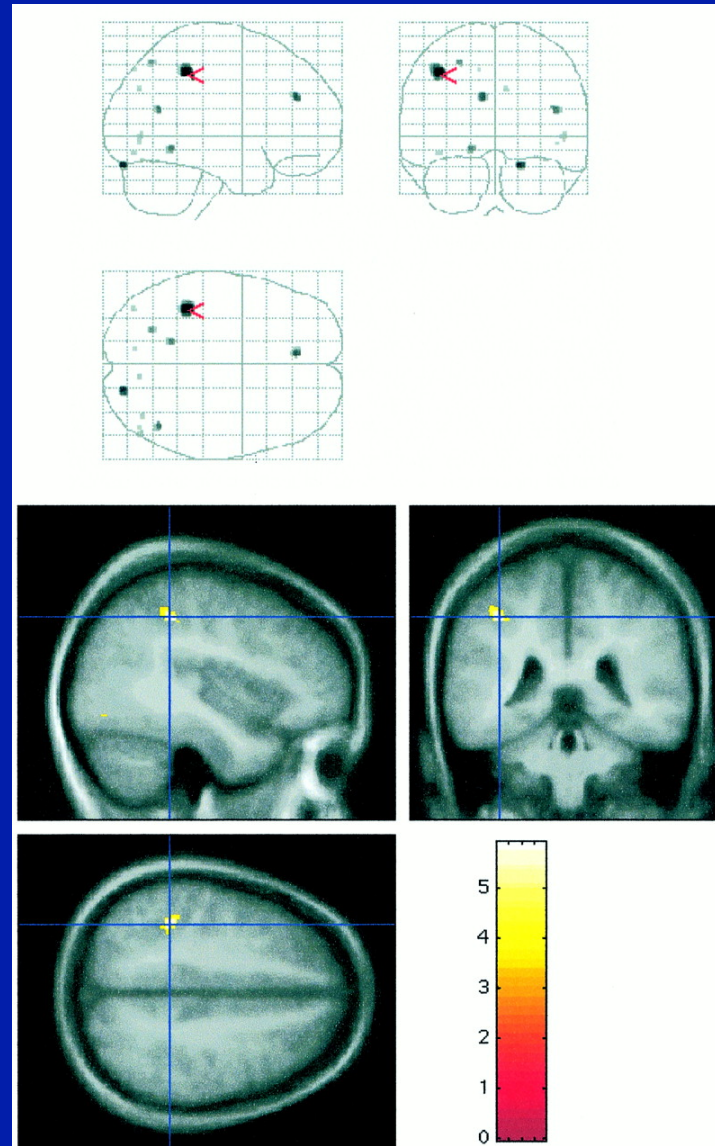
S de Turner :
Interruptions anormales

Abnormal shape and segmentation of the right IPS in three TS subjects



S. De Turner :
Anomalies de direction et ou branches

Reduced grey matter in VLBW adolescents poor on simple number tests



From Isaacs et al,
Brain, 2001

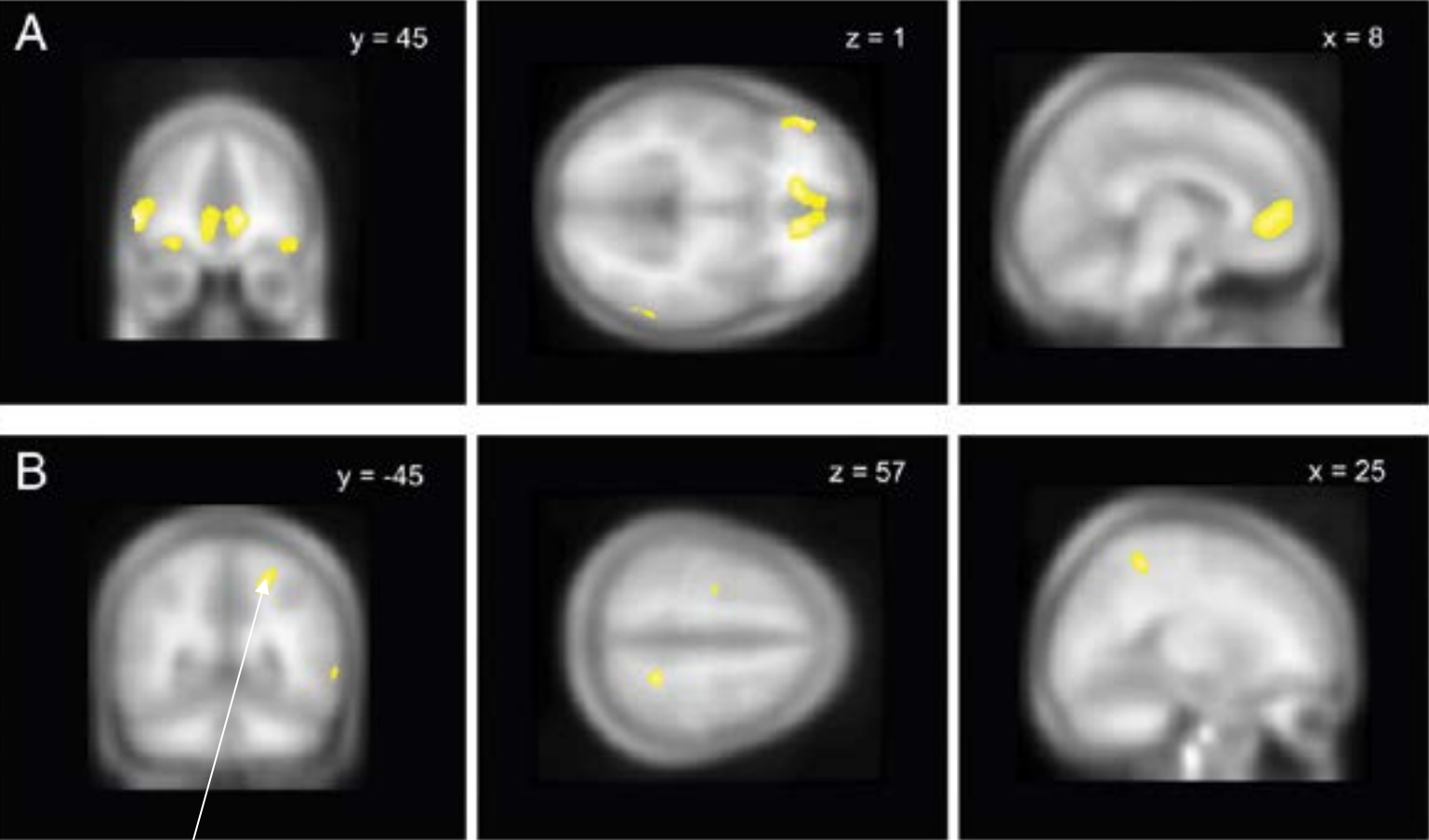
Optimized voxel-based morphometry in children with developmental dyscalculia

S. Rotzer,^{a,*} K. Kucian,^{a,1} E. Martin,^a M. von Aster,^{a,c} P. Klaver,^a and T. Loenneker^{a,b}

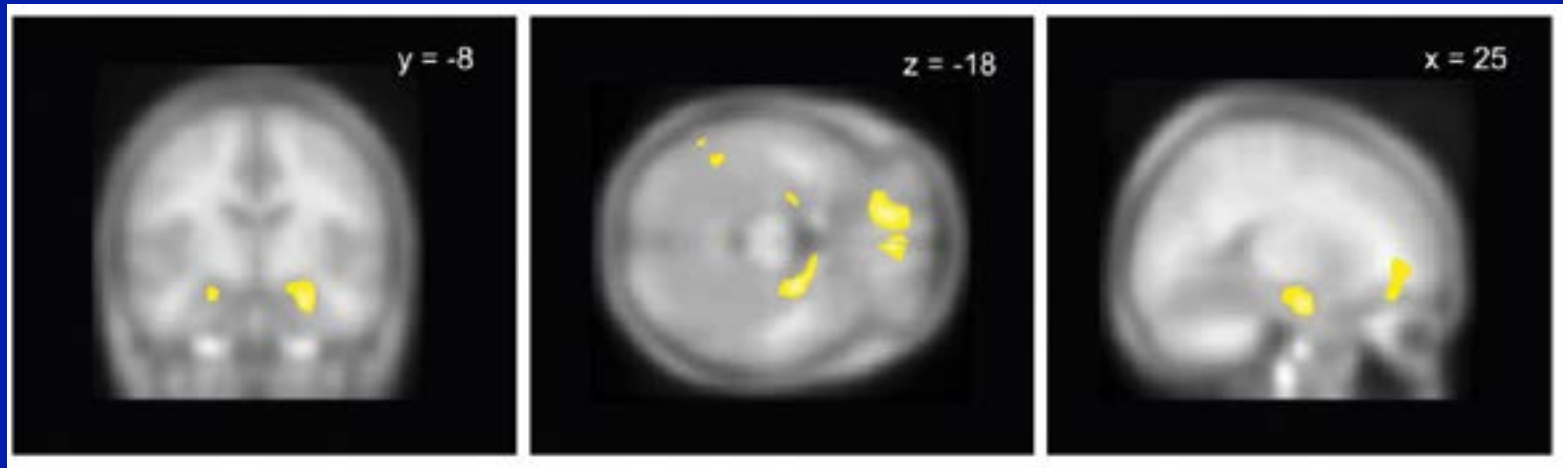
^aUniversity Children's Hospital, MR-Center, Steinwiesstrasse 75, CH-8032 Zurich, Switzerland

^bCenter for Integrative Human Physiology, University of Zurich, Switzerland

^cDepartment of Child and Adolescent Psychiatry, German Red Cross Hospitals Westend, Berlin, Germany



Right intra-parietal sulcus
controls more grey matter



White matter : decreased right para-hippocampal volume (spatial memory)

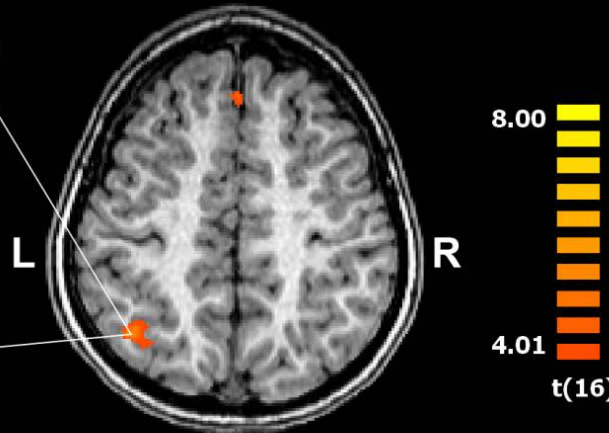
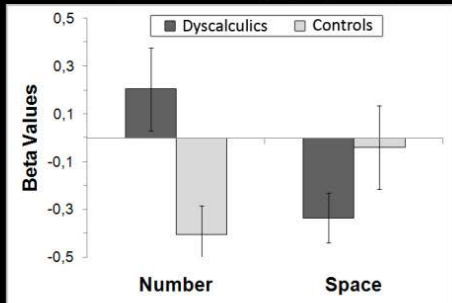
Research

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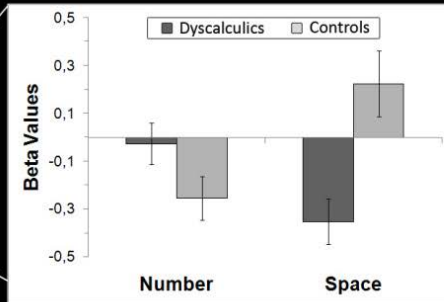
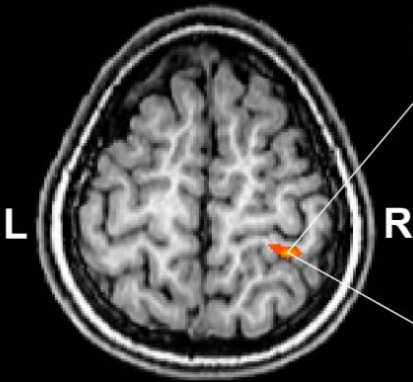
Developmental dyscalculia: compensatory mechanisms in left intraparietal regions in response to nonsymbolic magnitudes

Liane Kaufmann^{*1,2}, Stephan E Vogel^{1,3}, Marc Starke^{2,3}, Christian Kremser⁴, Michael Schocke⁴ and Guilherme Wood^{2,5}

Left inferior parietal lobe (x,y,z) = -39, -58, 43



Right inferior parietal lobe (x,y,z) = 30, -40, 55



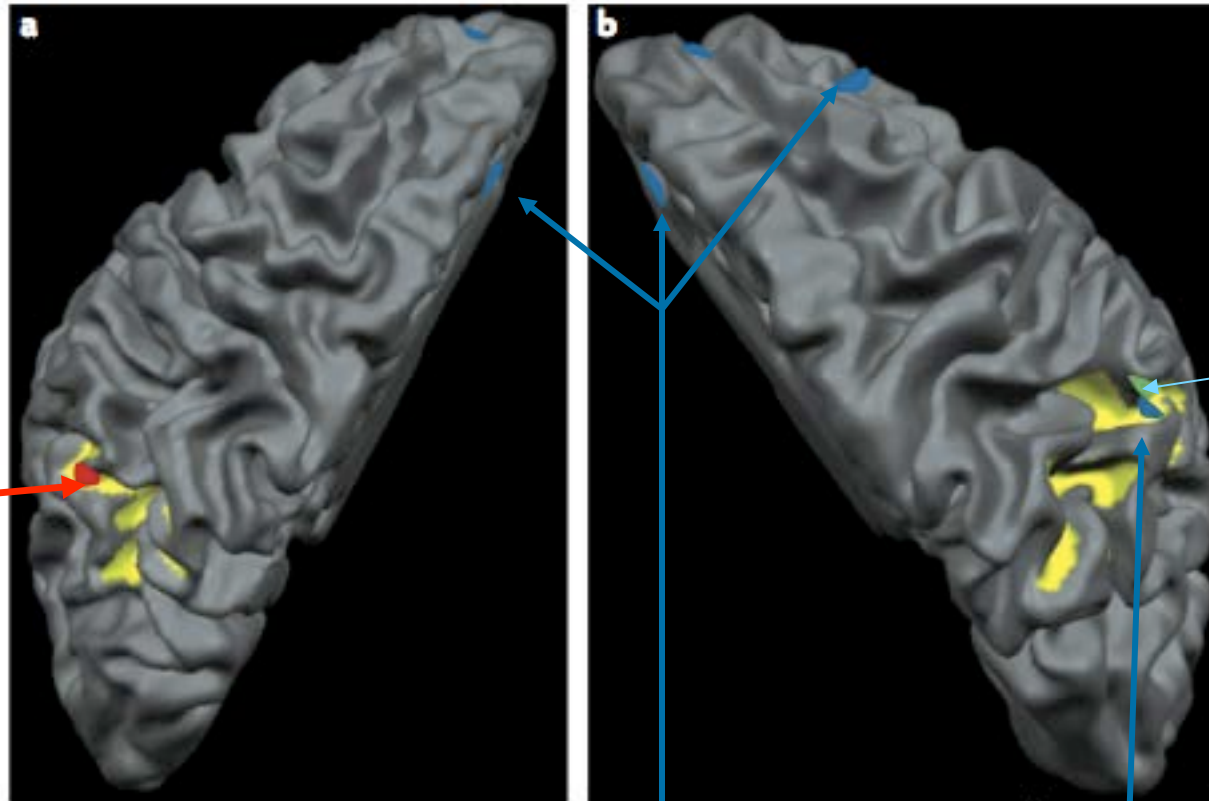
Stimuli : paires de mains représentant des numérosités de face palmaire ou dorsale

Condition "nombre" : comparaison de numérosité

Condition "espace" : comparaison d'orientation (dos/palme)

Dyscalculiques : moindre déactivation en condition "nombre" dans IPS droit + suractivation compensatoire dans IPS gauche

Box 1 | Neural basis of developmental dyscalculia



Low birth weight and dyscalculia (Isaacs et al., 2001)

magnitude comparison task : Although the non-symbolic numerical distance task significantly modulated activity in the right IPS in the typically developing participants, this effect was absent in the children with developmental dyscalculia (Price et al., 2007)

children with developmental dyscalculia have less right-parietal grey matter and have grey matter abnormalities in regions of the frontal cortex (Rotzer et al., 2008)

Correspondences

Impaired parietal magnitude processing in developmental dyscalculia

Gavin R. Price¹, Ian Holloway²,
Pekka Räsänen³, Manu
Vesterinen¹ and Daniel Ansari²

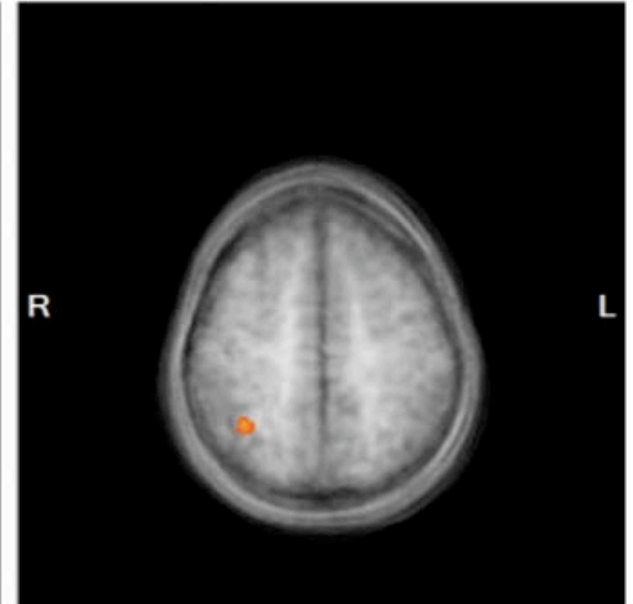
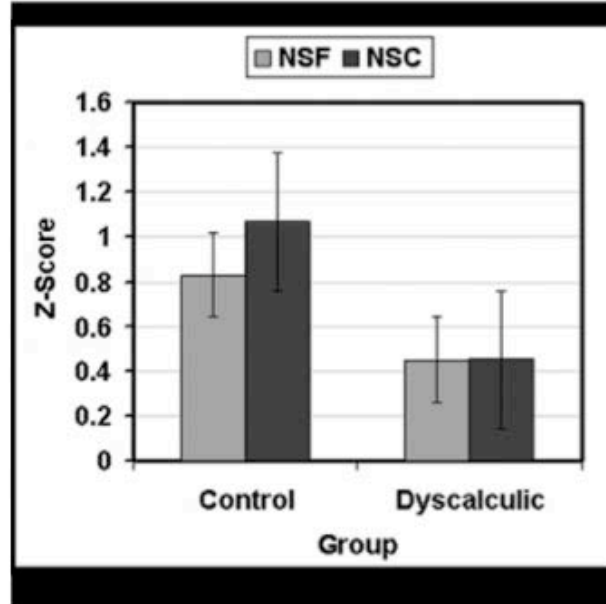
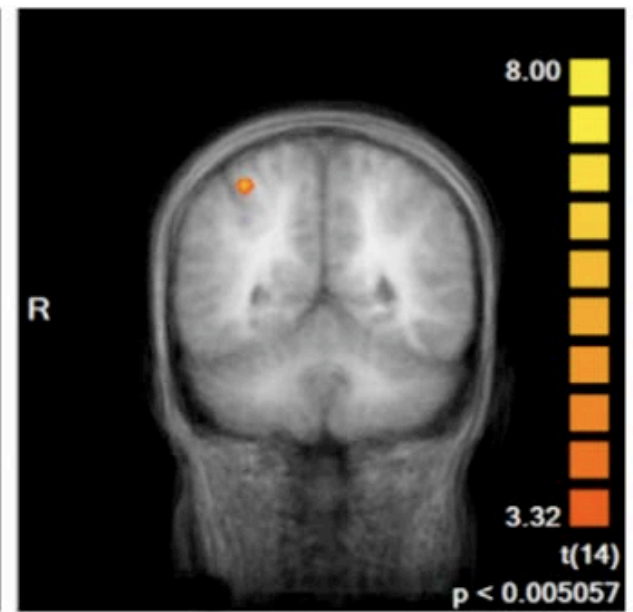
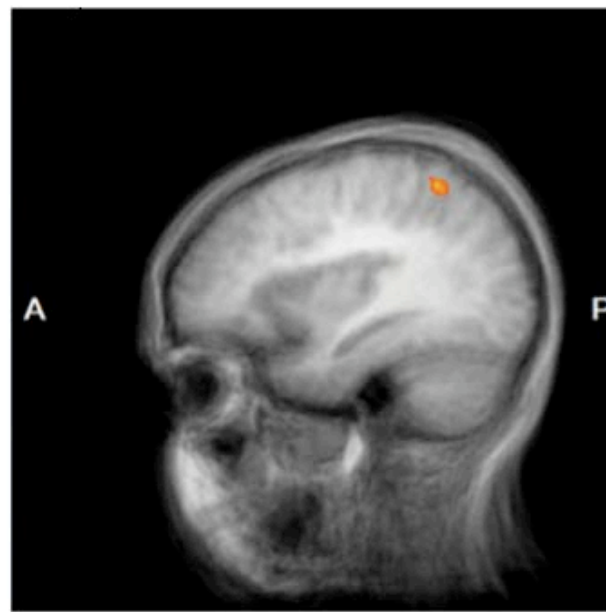
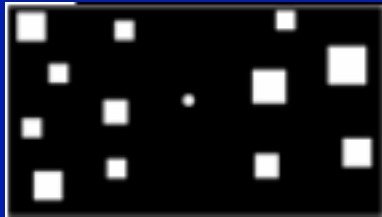
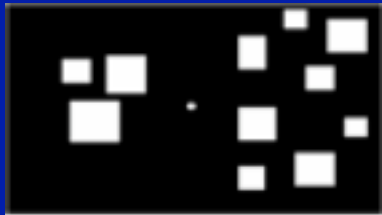


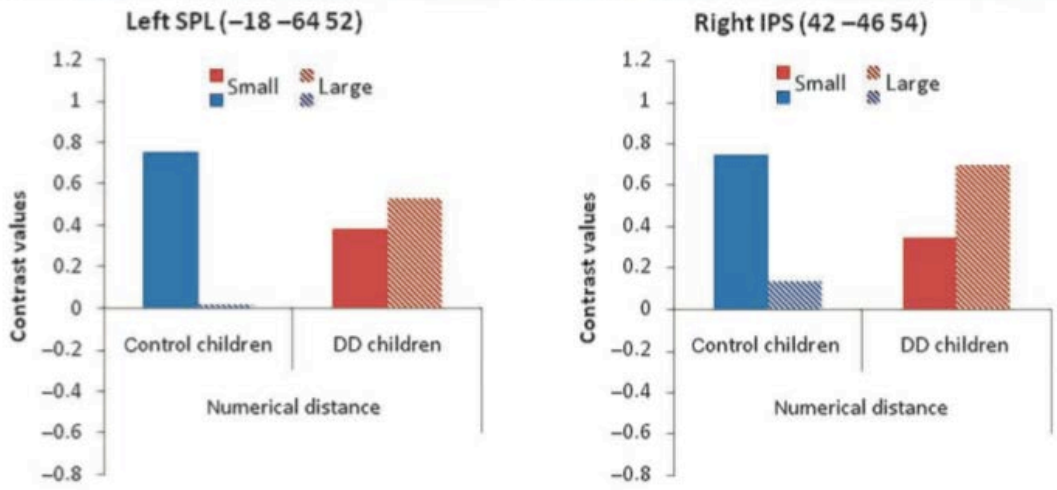
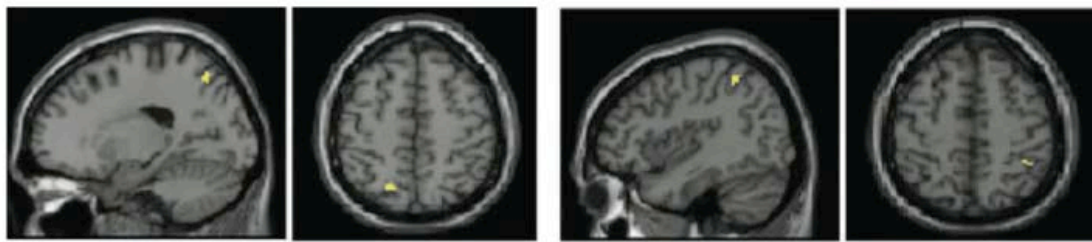
Figure 1. Interaction of group X distance in the right intraparietal sulcus.

NSC



NSF





Brain activation in bilateral intraparietal sulcus (IPS) was modulated by numerical distance in controls but not in children with DD. Moreover, although the right IPS responded to numerical distance only, the left IPS was influenced by both numerical and color distances in control children. Our findings suggest that dyscalculia is associated with impairment in areas involved in number magnitude processing and, to a lesser extent, in areas dedicated to domain-general magnitude processing.

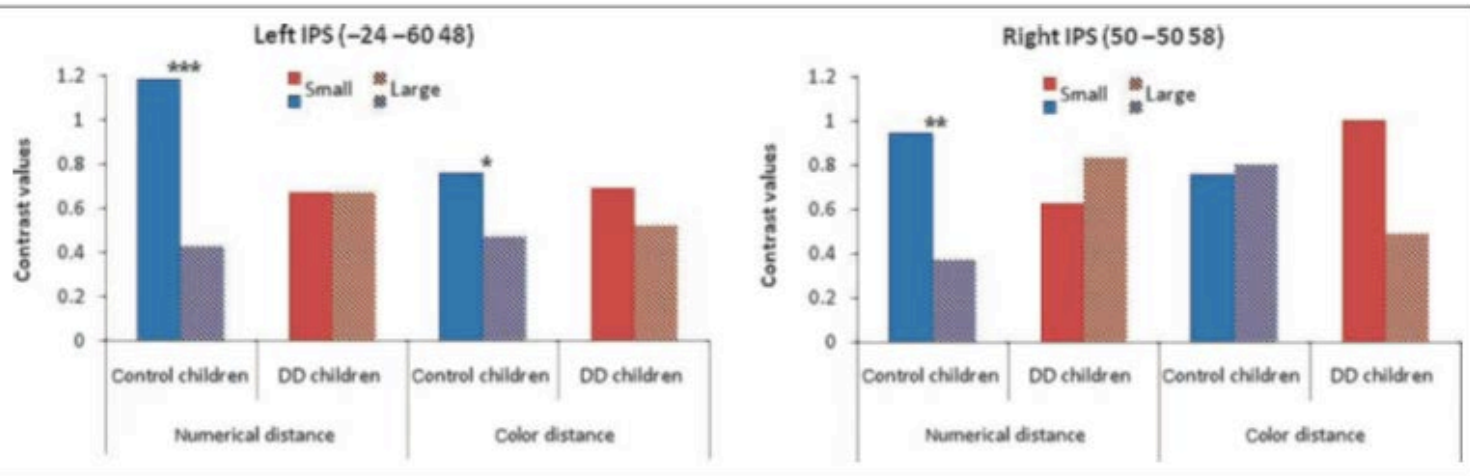


Figure 3. ROI analysis. Bar charts depict modulation of brain activation (mean contrast values) in left and right IPS during numerical and color distances, as computed in these regions for both control and DD children. Significant group differences are marked with one (* $p_{corrected} < .05$), two (** $p_{corrected} < .01$), or three asterisks (***) ($p_{corrected} < .001$), corrected for multiple comparisons.

Troisième conclusion

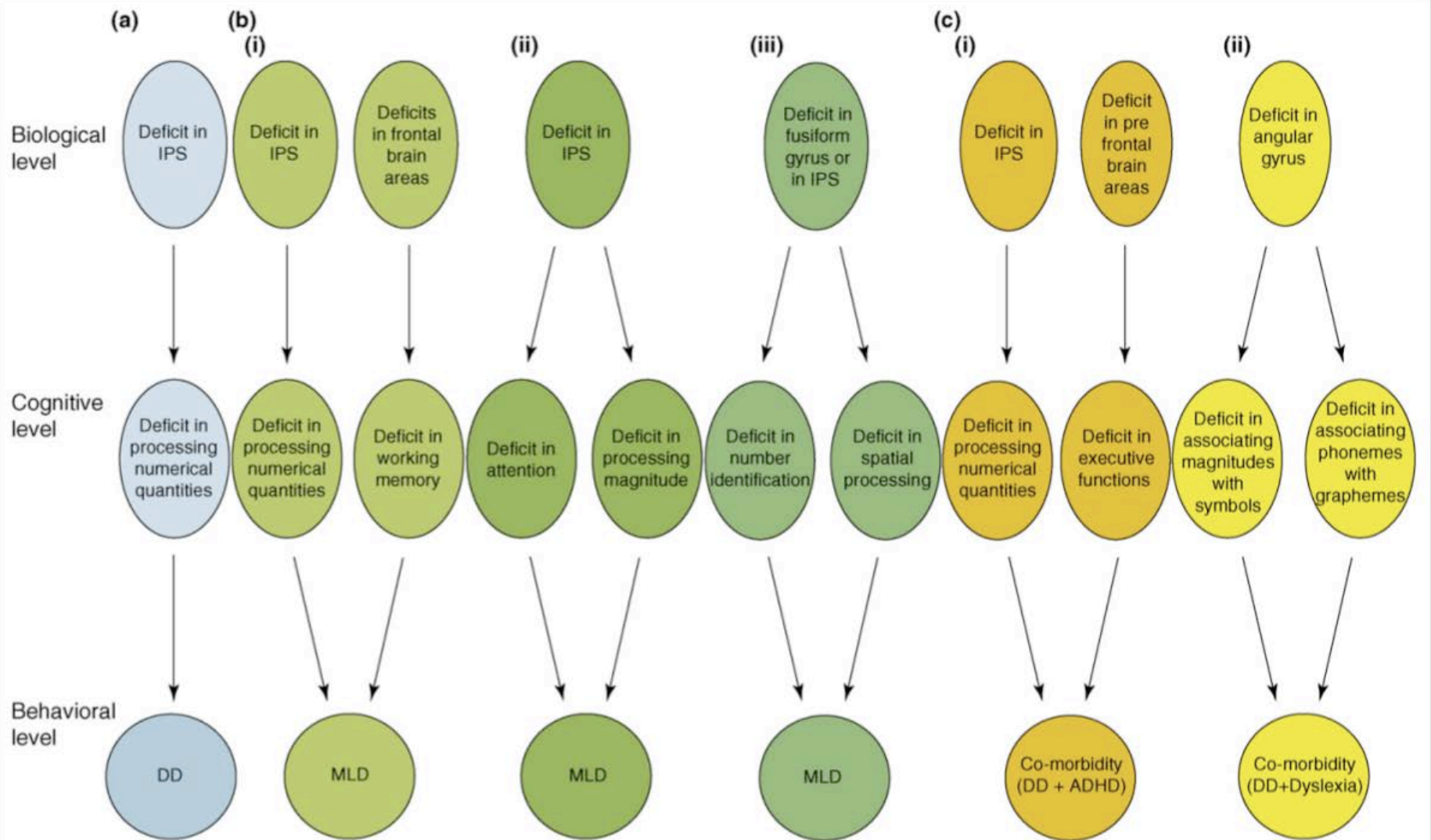
- Il existe un nombre croissant d'arguments suggérant que la dysfonction caractéristique de la dyscalculie se situe au niveau de l'IPS
- La latéralisation de cette dysfonction pariétale est variable, le plus souvent à droite
- La modulation de l'activation de l'IPS par la distance numérique est un argument en faveur d'un trouble spécifique de la représentation des magnitudes
- La dysfonction de l'IPS ne serait pas spécifique aux nombres et serait amodale

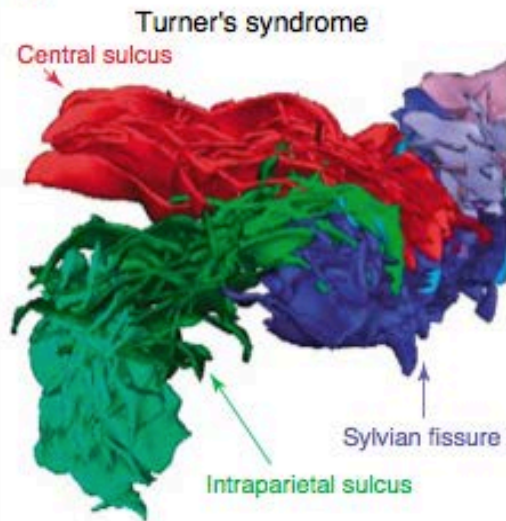
Developmental Dyscalculia: heterogeneity might not mean different mechanisms

Orly Rubinsten¹ and Avishai Henik²

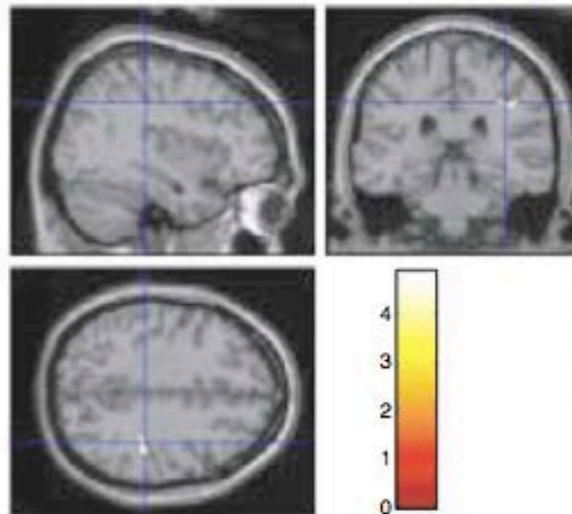
¹Edmond J. Safra Brain Research Center for the Study of Learning Disabilities, Department of Learning Disabilities, University of Haifa, Israel

²Department of Psychology and Zlotowski Center for Neuroscience, Ben-Gurion University of the Negev, Beer-Sheva, Israel

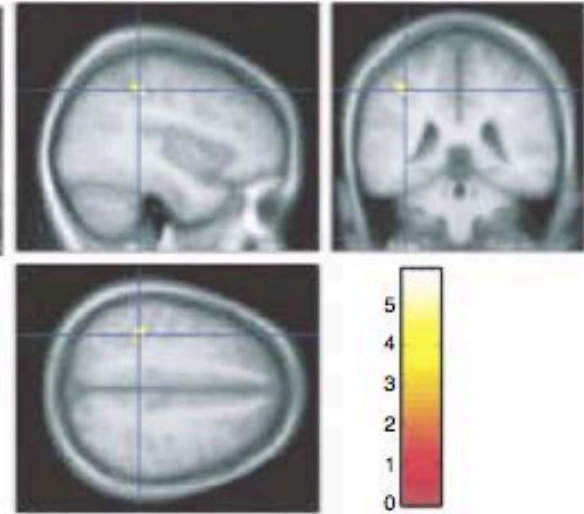


(a)

Turner's syndrome (coords 43, -30, 37)



Prematurity (coords -39, -39, 45)

**(b)**

Lack of increase with problem size in Turner's syndrome compared to controls



Lack of increase with number of operands in Fragile X syndrome compared to controls



Current Opinion in Neurobiology

Convergence of neuroimaging results in dyscalculia. **(a)** Anatomical findings include an abnormal shape and depth of the IPS in Turner's syndrome [63*] and missing gray matter in the left or right IPS in both Turner's syndrome [63*] and adolescents born premature and suffering from developmental dyscalculia [62]. **(b)** Functional activation findings indicate an abnormal inability to recruit the IPS as arithmetic difficulty increases, in both Turner's [63*] and fragile X [66] syndromes.



Neuroanatomical correlates of developmental dyscalculia: combined evidence from morphometry and tractography

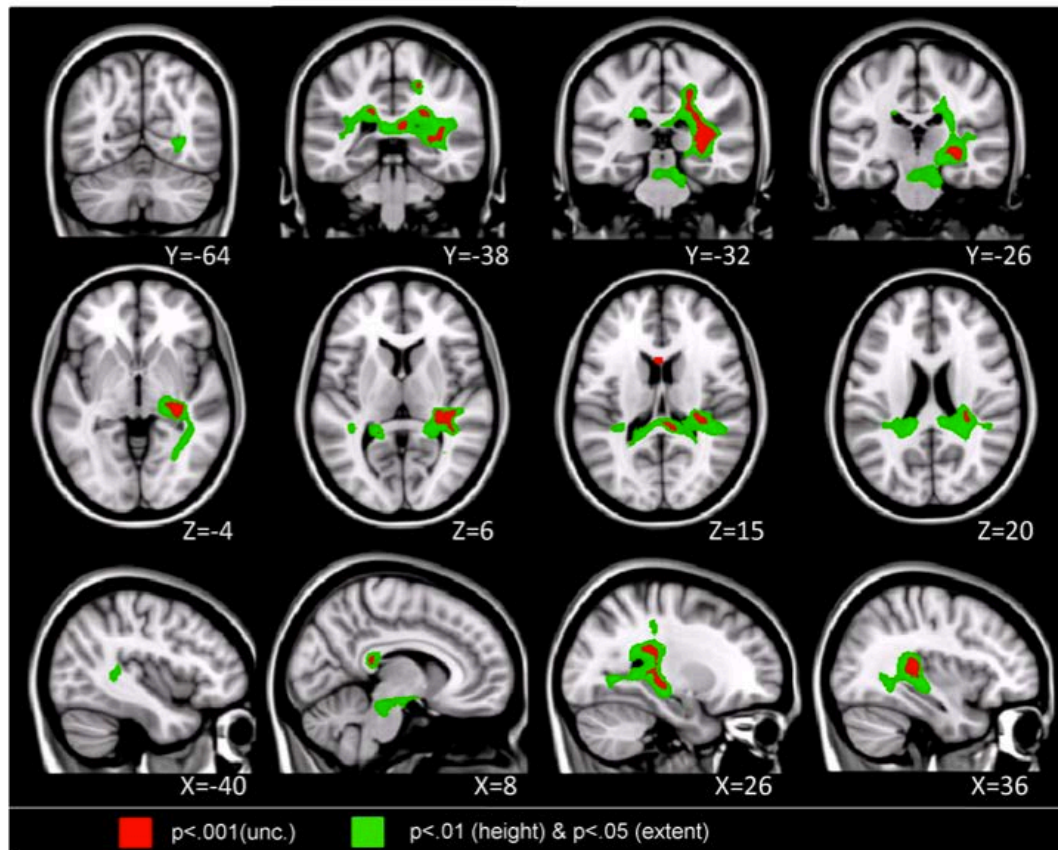
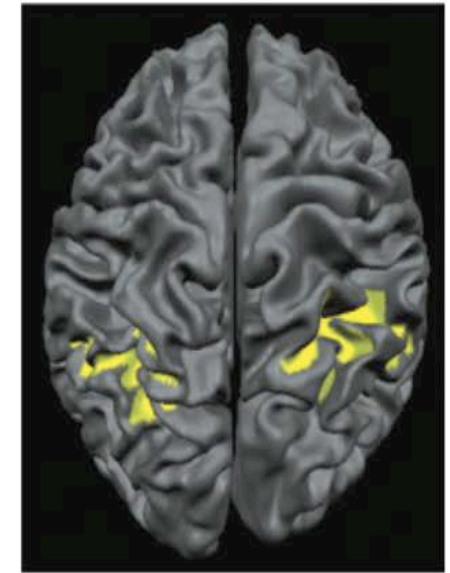
Elena Rykhlevskaia^{1,2}, Lucina Q. Uddin¹, Leeza Kondos¹ and Vinod Menon^{1,3,4*}

¹ Department of Psychiatry and Behavioral Sciences, Stanford University, CA, USA

² Department of Psychology, Stanford University, CA, USA

³ Program in Neuroscience, Stanford University, CA, USA

⁴ Symbolic Systems Program, Stanford University, CA, USA



DTI tractography suggests that long-range WM projection fibers linking the right fusiform gyrus with temporal-parietal WM are a specific source of vulnerability in DD

FIGURE 2 | Brain regions where children with DD showed significant white matter deficits, compared to TD children (two-sample t-test results for TD > DD contrast). Red: $p < 0.001$; Green: height threshold $p < 0.01$, extent threshold $p < 0.05$ with family-wise error correction for multiple comparisons and correction for non-isotropic smoothness.

The Number Race




<http://www.unicog.org/main/page.php?page=numberrace>



Protocole d'entraînement

- Entraînement quotidien, 1/2 heure par jour durant 4 semaines
- Design expérimental : la population totale a été divisée en deux groupes représentant approximativement la moitié de chacune des deux classes. Deux sessions de 4 semaines séparées par les vacances de février
- 3 mesures des capacités arithmétiques scolaires à T₀, T₁ et T₂
- Le groupe 1 a réalisé l'entraînement lors des 4 premières semaines (T₀ à T₁), le groupe 2 pendant les 4 semaines suivantes (T₁ à T₂)

→

?




		2
	• • • •	4

?

4




5

→

?


$6-4=2$









$4+0=4$



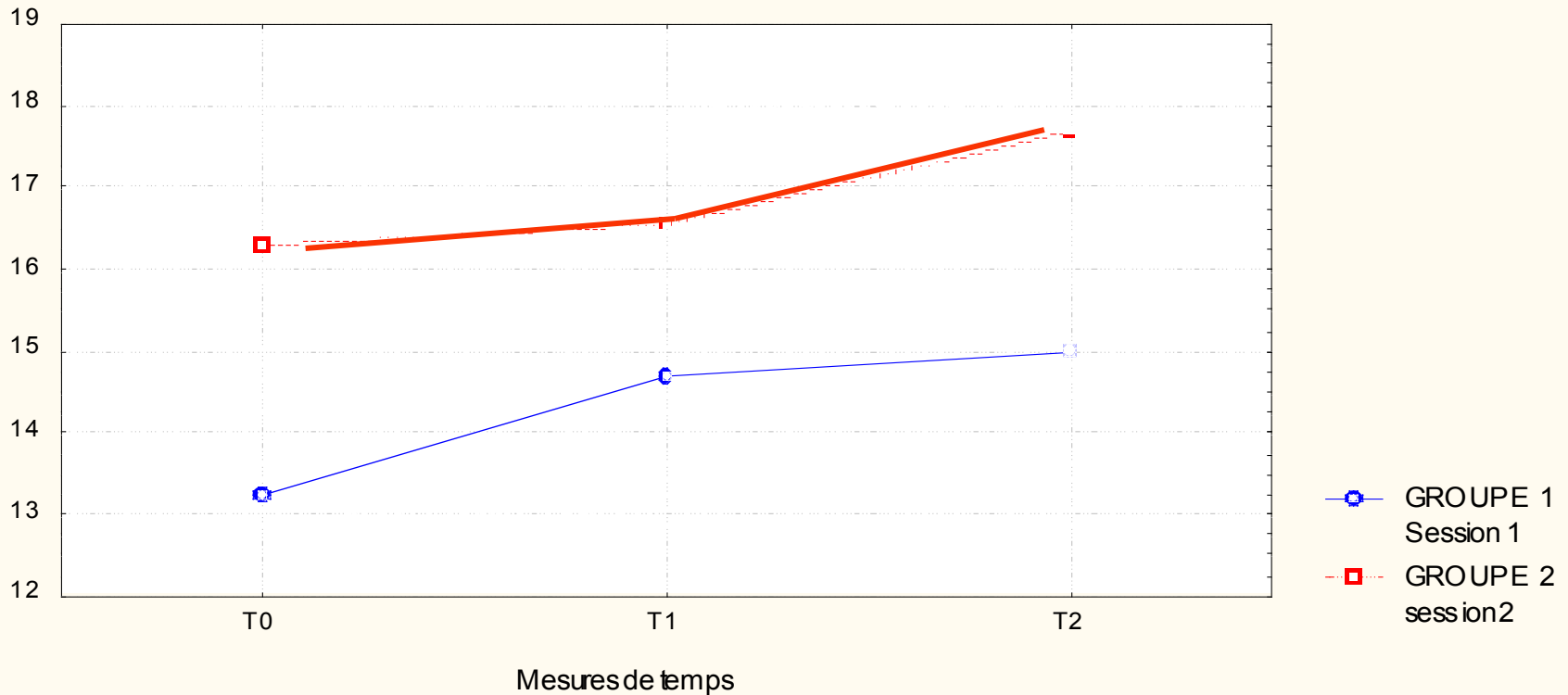

		

→

?

Tracé de Moyennes
2^oordre intéreact
 $F(2,88)=1,93;p<,1510$



Effet d'un entraînement de 4 semaines avec "la course aux nombres"
(score global évaluation nationale CE1)

Mental number line training in children with developmental dyscalculia

K. Kucian^{a,b,*}, U. Grond^{a,b}, S. Rotzer^a, B. Henzi^a, C. Schönmann^a, F. Plangger^a, M. Gälli^c, E. Martin^{a,b,d}, M. von Aster^{a,b,e}

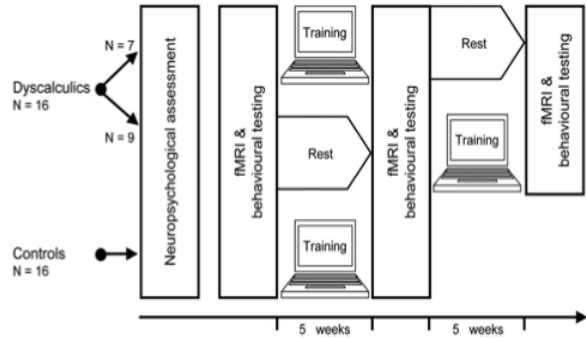
^a MR-Center, University Children's Hospital, Zurich, Switzerland
^b Pediatric Research Center, University Children's Hospital, Zurich, Switzerland
^c Methods in Action GmbH, Wollerau, Switzerland
^d Center for Integrative Human Physiology, University of Zurich, Zurich, Switzerland
^e Department of Child and Adolescent Psychiatry, German Red Cross Hospitals Westend, Berlin, Germany

ARTICLE INFO

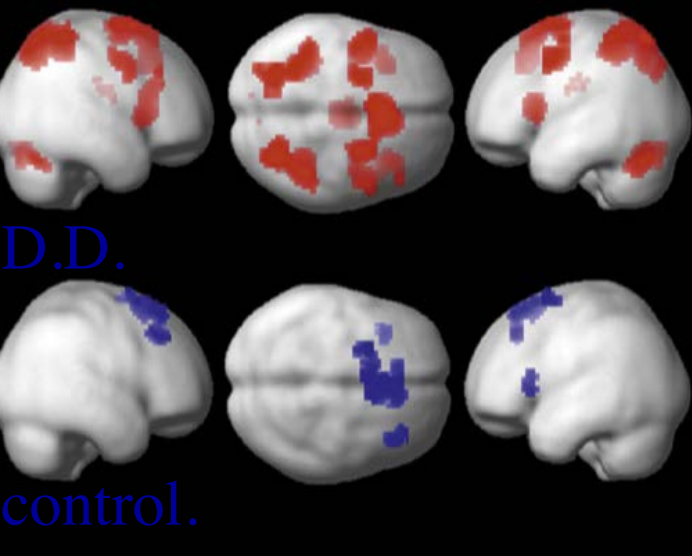
Article history:
 Received 30 June 2010
 Revised 25 January 2011

ABSTRACT

Developmental dyscalculia (DD) is a specific learning disability that affects the acquisition of math skills in children with normal intelligence and age-appropriate school education (prevalence 3-6%); an essential step in the development of mathematical understanding is the formation and automated access



Pre-Training
 (order vs. control task); $p < 0.01$, cluster-extent corrected



Après 5 semaines d'entraînement de la ligne numérique mentale, les deux groupes ont une réduction d'activité dans les régions frontales et pariétales, réduction plus nette chez les

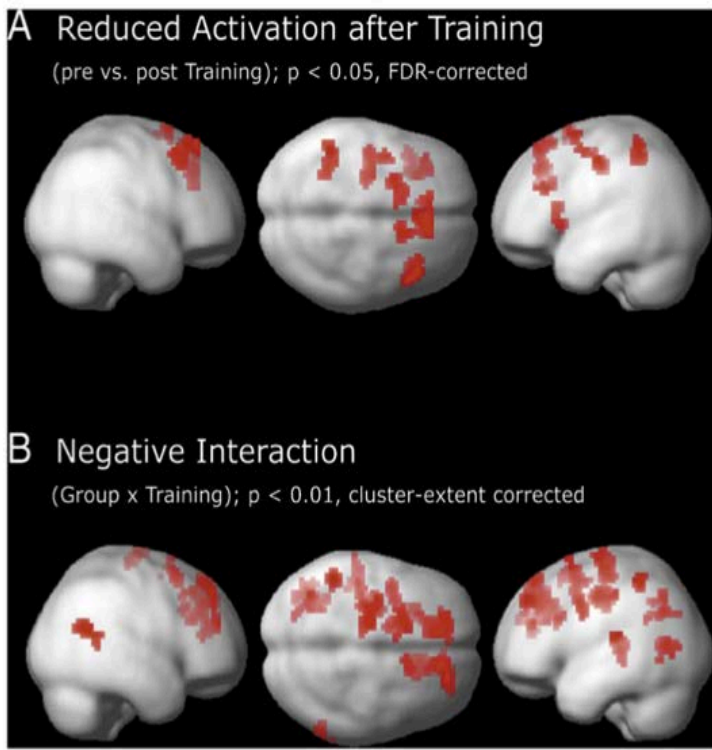


Fig. 6. Main effects of training. All illustrated results derive from the calculated ANOVA for the contrast order vs. control task. (A) Reduced brain activation for both groups after the training is shown at $p < 0.05$, FDR-corrected with a cluster size of 29 voxels or more. (B) Brain areas that showed a negative interaction between group and training are shown at $p < 0.01$, cluster-extent corrected.

