Functional contributions of the motor network in the ‘’handwriting brain’’

Véron-Delor Lauriane (LPL & LNC)
Cosupervision : Serge Pinto (LPL) & Jérémy Danna (LNC)
Collaborations : A. Eusebio, T. Witjas, J.-P. Azulay, INT et Service Neurologie, pathologie du mouvement – AP-HM Hôpital la Timone, M. Longcamp, J.-L. Velay, LNC, Julien Sein, Bruno Nazarian, Jean-Luc Anton, CERIMED

The specific features of handwriting

- A movement for communication

Key processes in word production

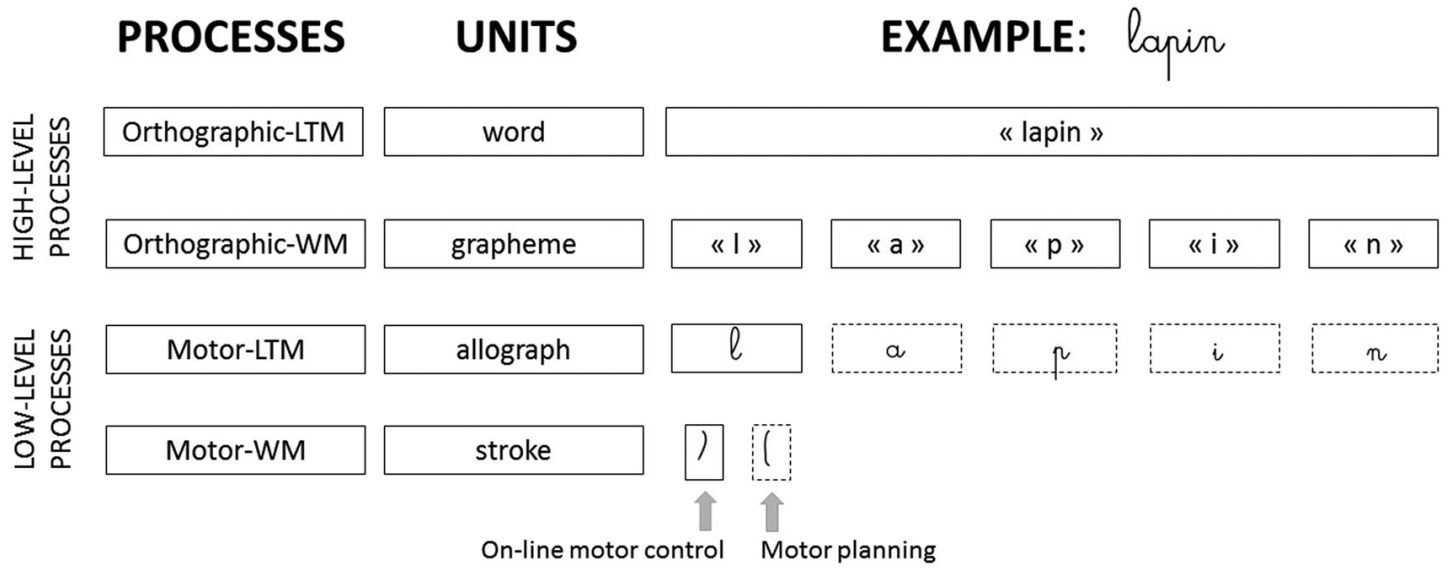
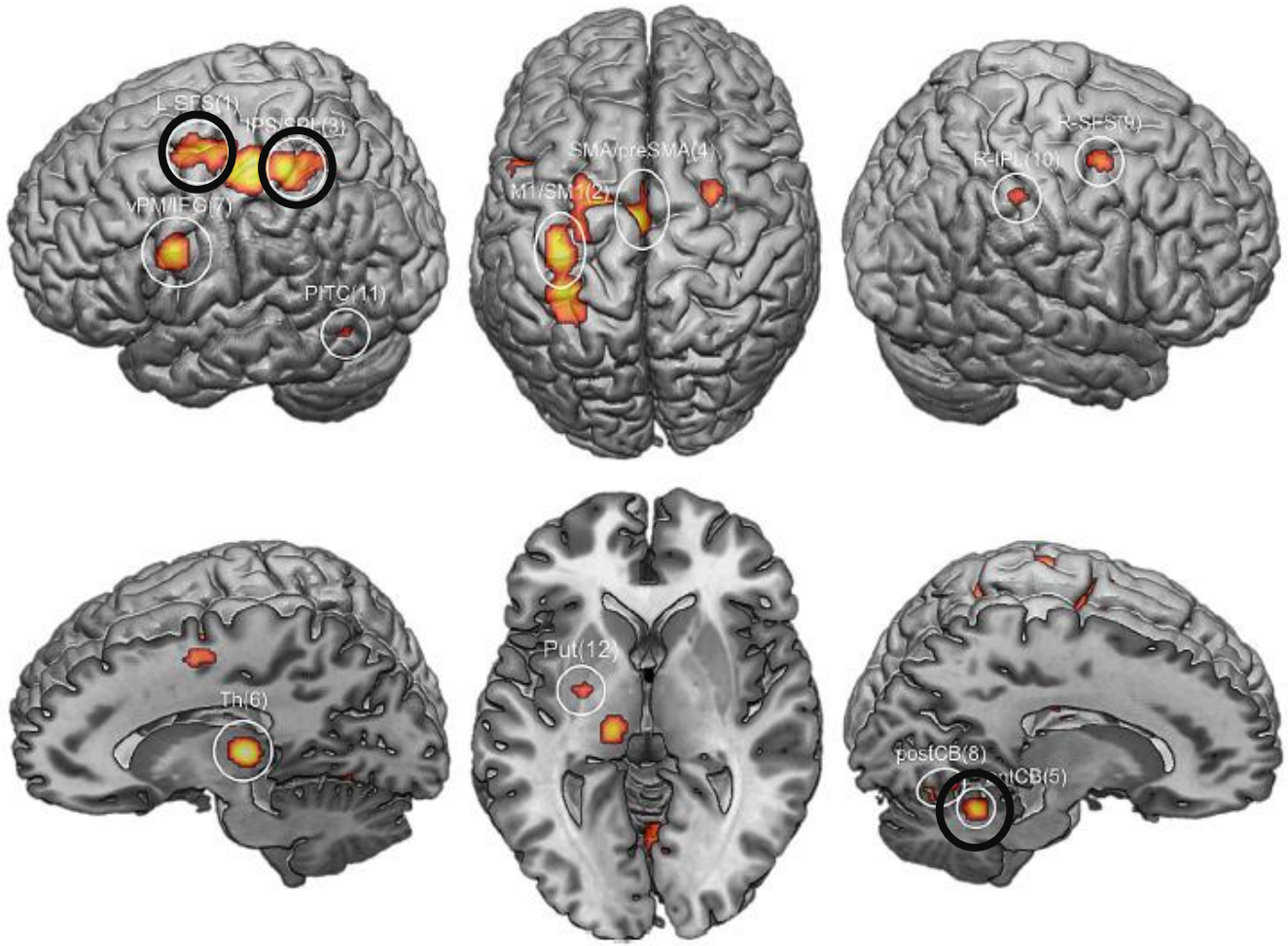


Figure 1. Schematic illustration of the different key processes and units activated during the production of the first stroke of the French word “lapin” (rabbit) in cursive handwriting. LTM = long-term memory; WM = working memory.

Palmis *et al.*, 2017

The « handwriting brain »

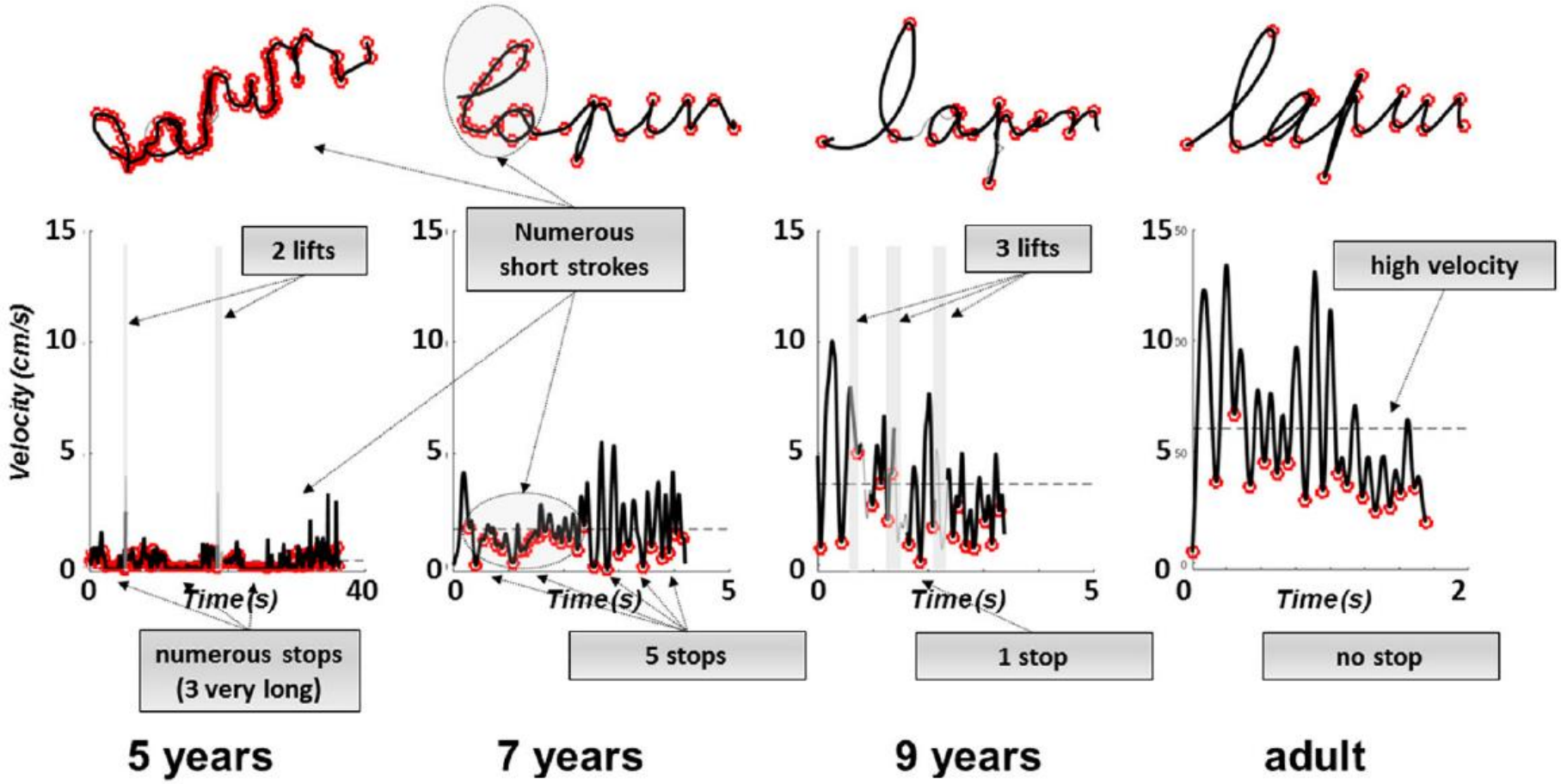


In Planton *et al.,* 2013

The specific features of handwriting

- A movement for communication
- An artefact that requires several years of practice

The specific features of handwriting



Palmis *et al.*, 2017

The specific features of handwriting

PERGAMON

Neural Networks 13 (2000) 999–1046

Neural Networks

www.elsevier.com/locate/neunet

2000 Special Issue

A neural model of cortico-cerebellar interactions during attentive imitation and predictive learning of sequential handwriting movements

S. Grossberg[1,*], R.W. Paine[2]

Department of Cognitive and Neural Systems, Boston University, 677 Beacon Street, Boston, MA 02215, USA

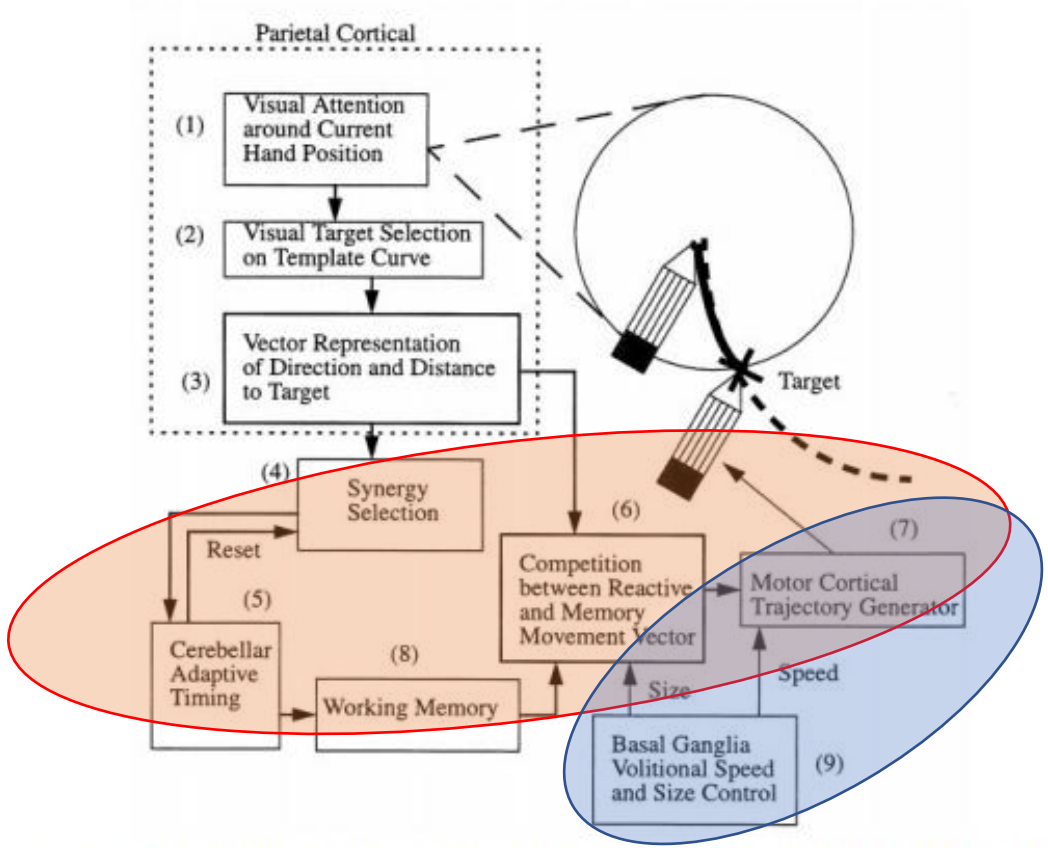


Fig. 3. Conceptual diagram of the AVITEWRITE architecture. Numbers in parentheses indicate the order of discussion in the text.

The specific features of handwriting

- A movement for communication
- An artefact that requires several years of practice
- A movement that produces a written trace

On the importance of the motor component in handwriting (and reading)

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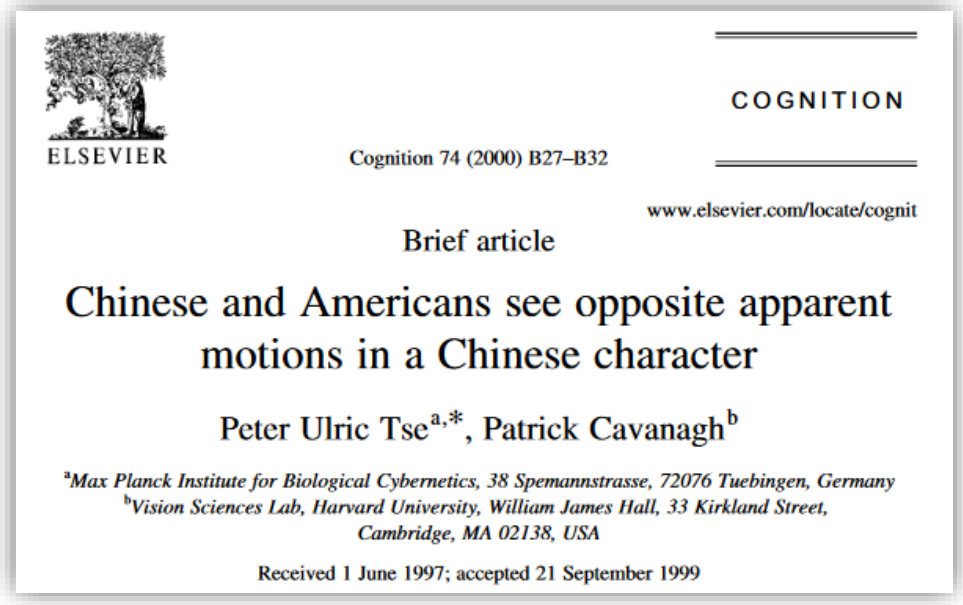


ELSEVIER

COGNITION

Cognition 74 (2000) B27–B32

www.elsevier.com/locate/cognit

Brief article

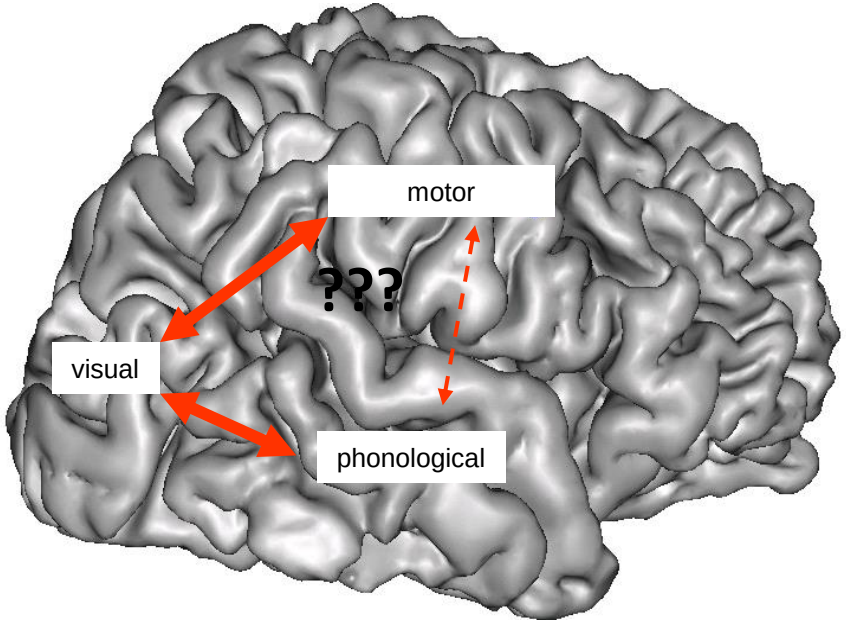
Chinese and Americans see opposite apparent motions in a Chinese character

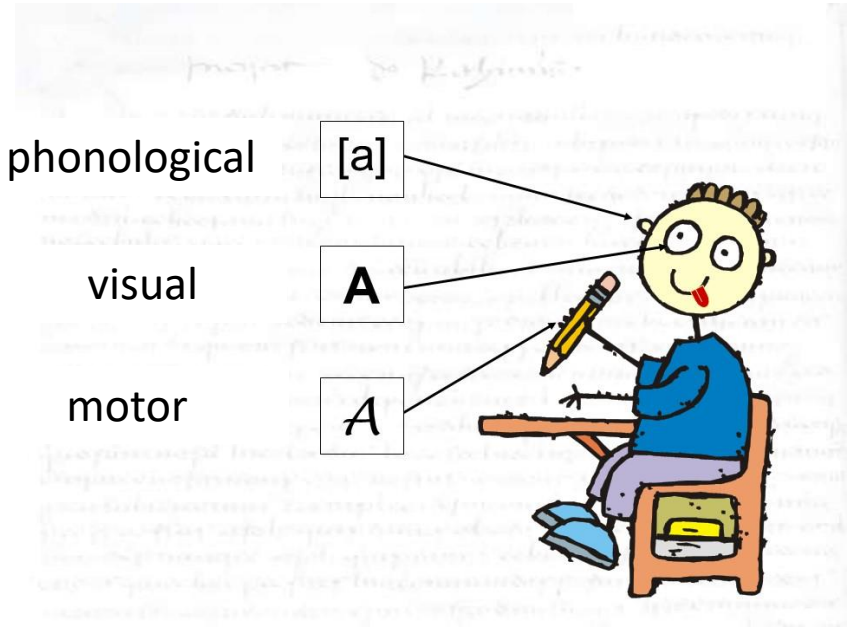
Peter Ulric Tse[a,*], Patrick Cavanagh[b]

[a]*Max Planck Institute for Biological Cybernetics, 38 Spemannstrasse, 72076 Tuebingen, Germany*
[b]*Vision Sciences Lab, Harvard University, William James Hall, 33 Kirkland Street, Cambridge, MA 02138, USA*

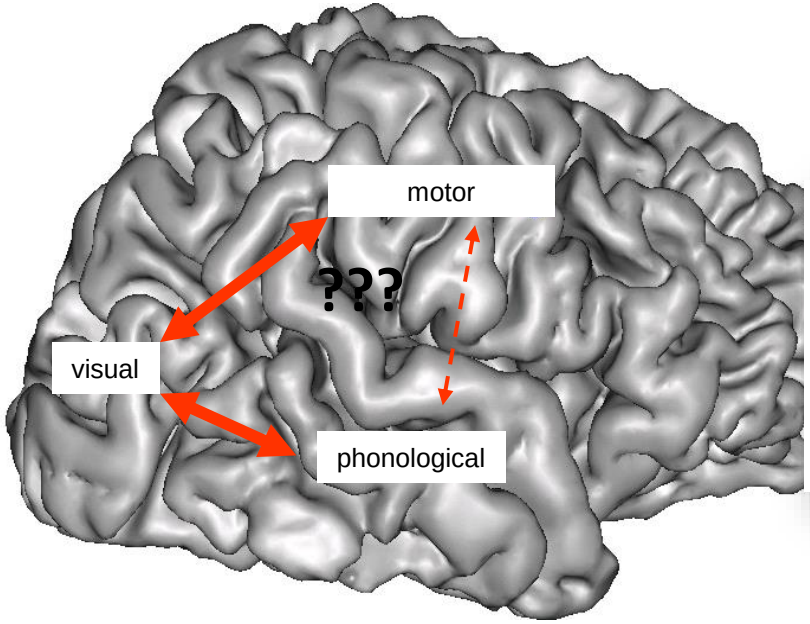
Received 1 June 1997; accepted 21 September 1999

On the importance of the motor component in handwriting (and reading)





On the importance of the motor component in handwriting (and reading)



phonological [a]

LES BASES NERVEUSES DU CONTRÔLE VISUO-MANUEL DE L'ÉCRITURE

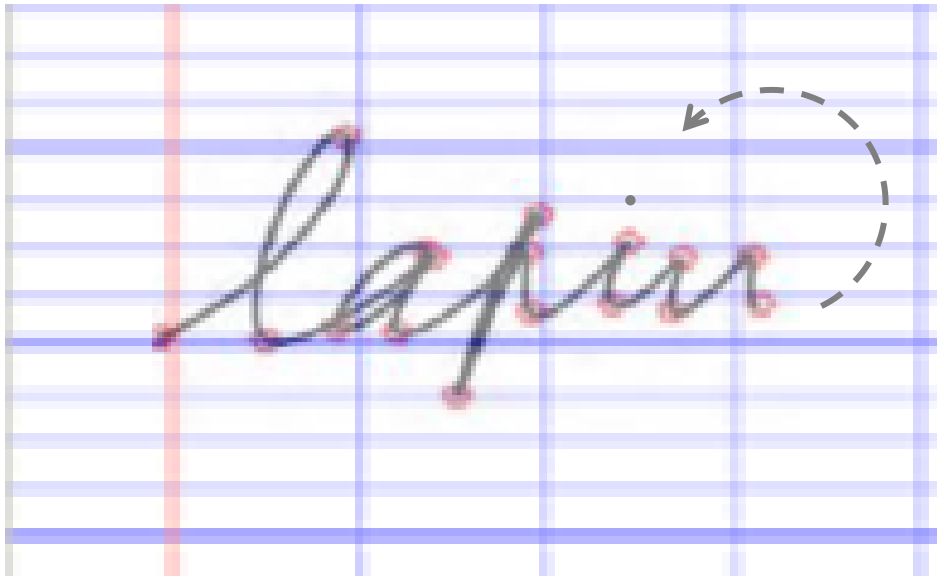
Jacques PAILLARD*

Handwriting features

- The morphokinetic component responsible for the production of the shapes of the letters
  - ➔ require to produce **the strokes that constitutes the letters**

Handwriting features

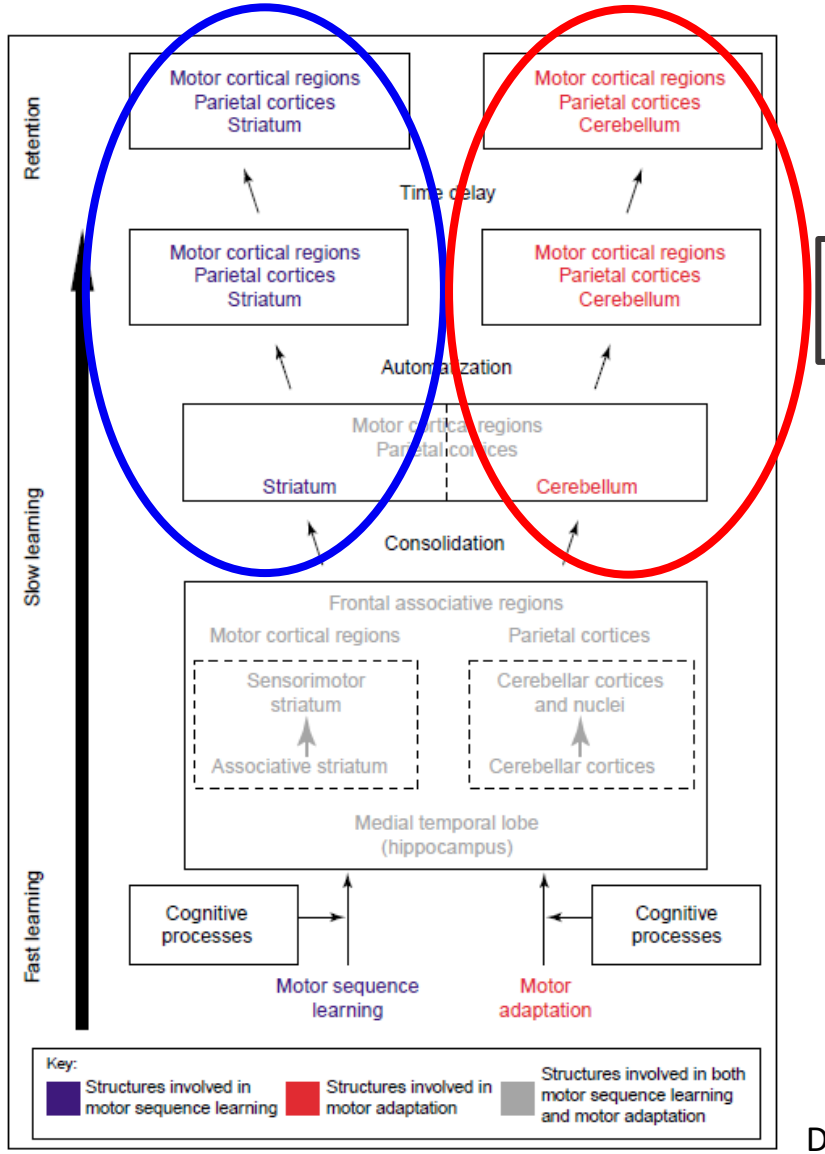
- The morphokinetic component responsible for the production of the shapes of the letters
  - ➔ require to produce **the strokes that constitutes the letters**
- The topokinetic component enabling the spatial layout of the letters on the page
  - ➔ Require to **adapt** the pen movement to spatial constraints



Handwriting features

Handwriting sequential component

Cortico-striatal loops



Adaptation to visuo-spatial constraints

Cortico-cerebellar loop

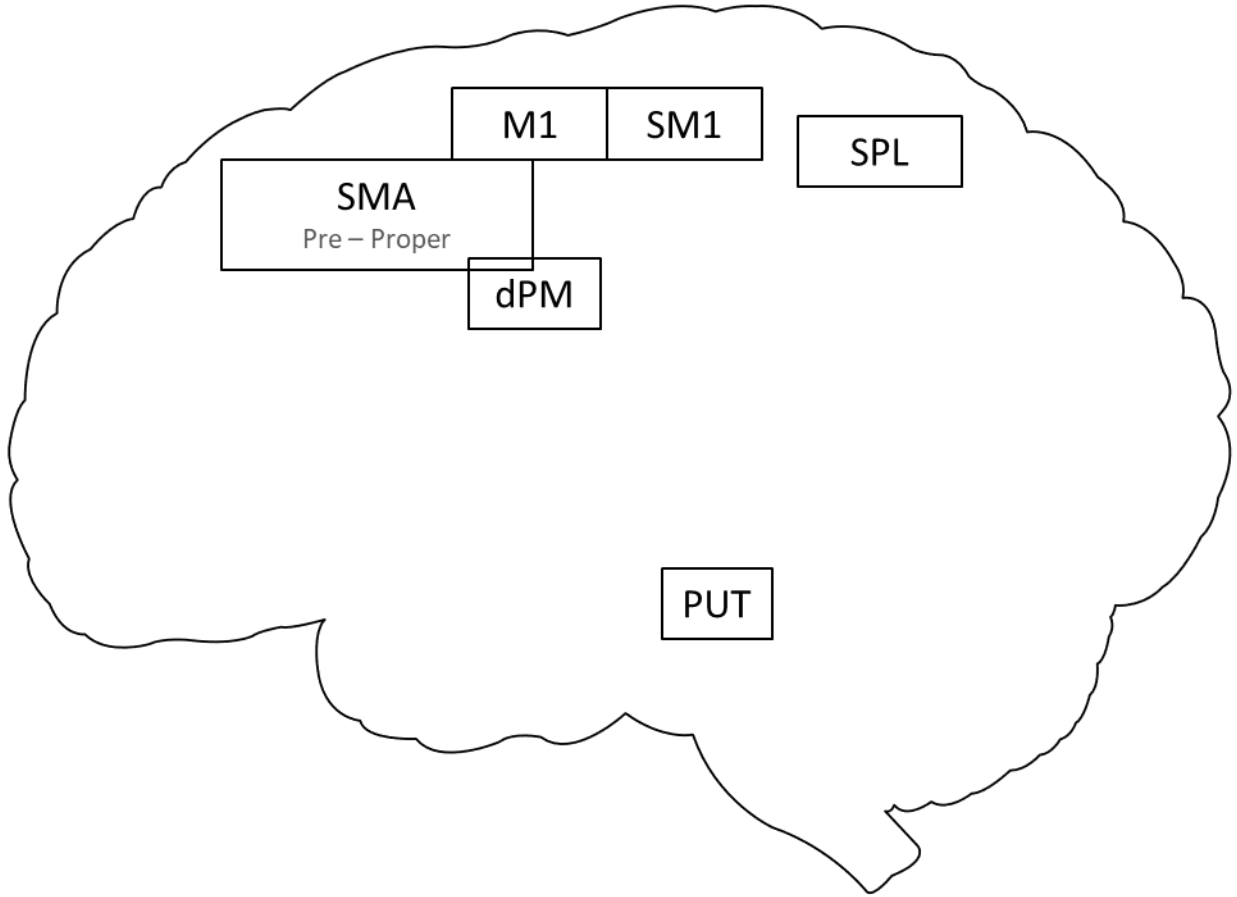
Doyon & Benali, 2005

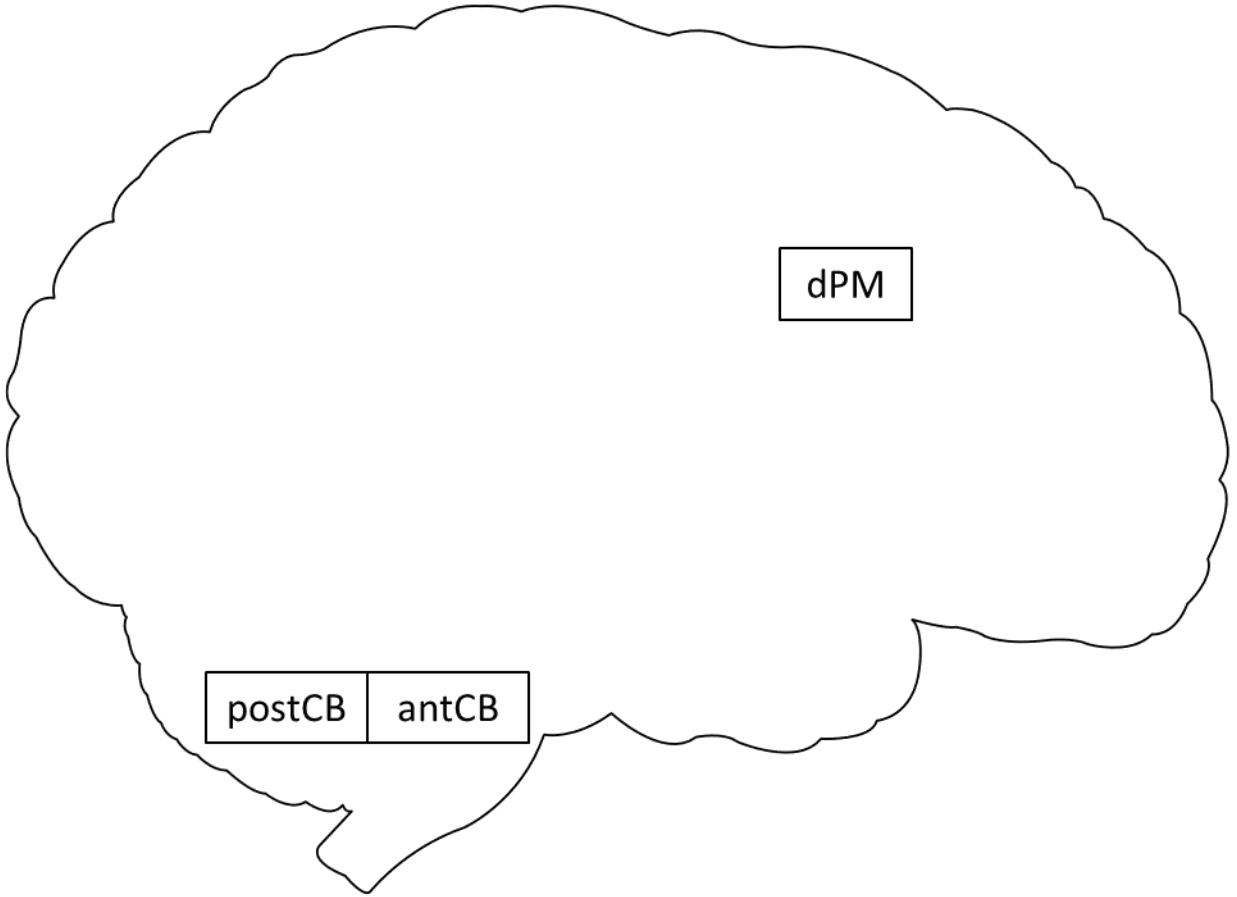
Hypotheses

The sequential complexity of the motor unit (morphokinetic component) would modulate the activation of the cortico-striatal loop

The increase of spatial constraints in handwriting (topokinetic component) would increase the activation of the cortico-cerebellar loop (motor adaptation)

The motor network in the « handwriting brain »





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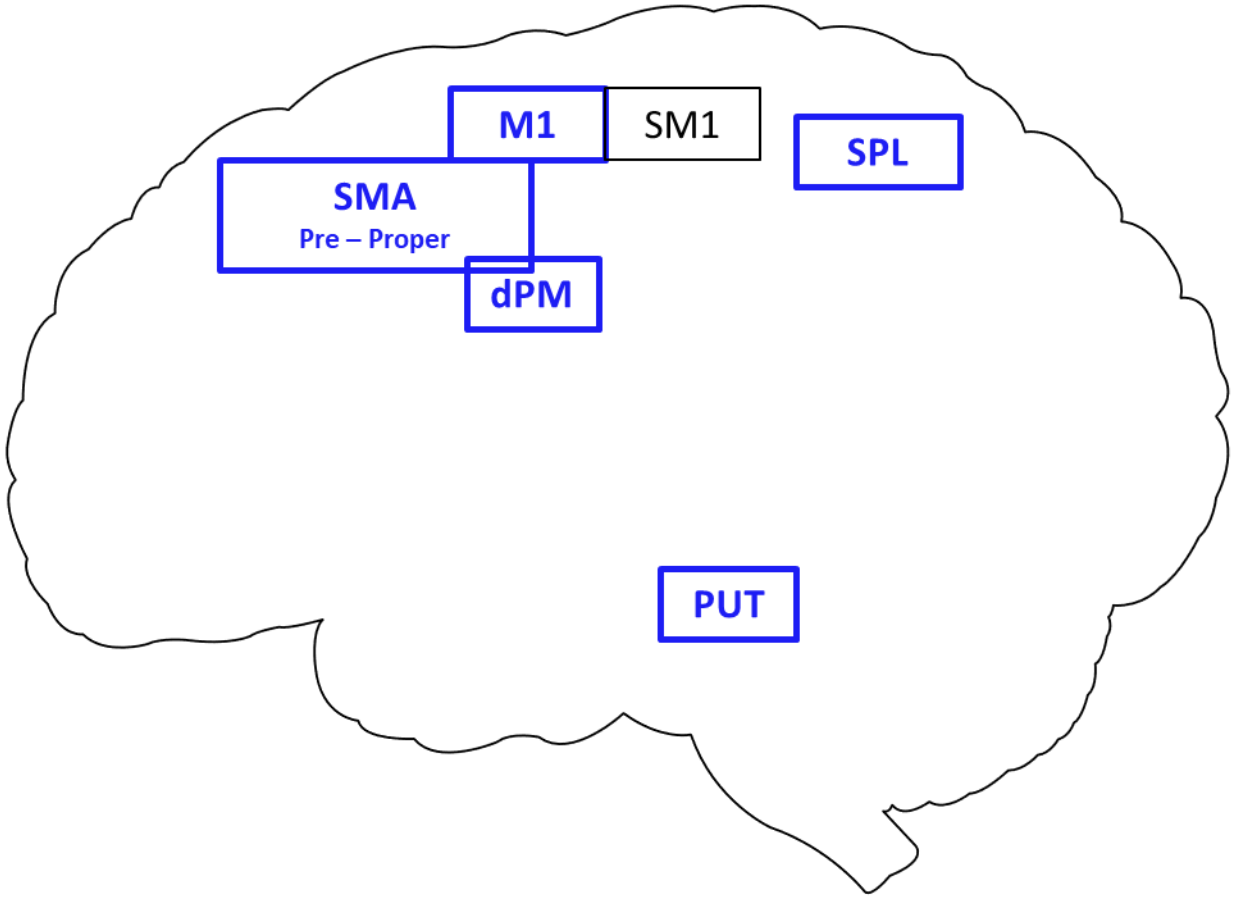
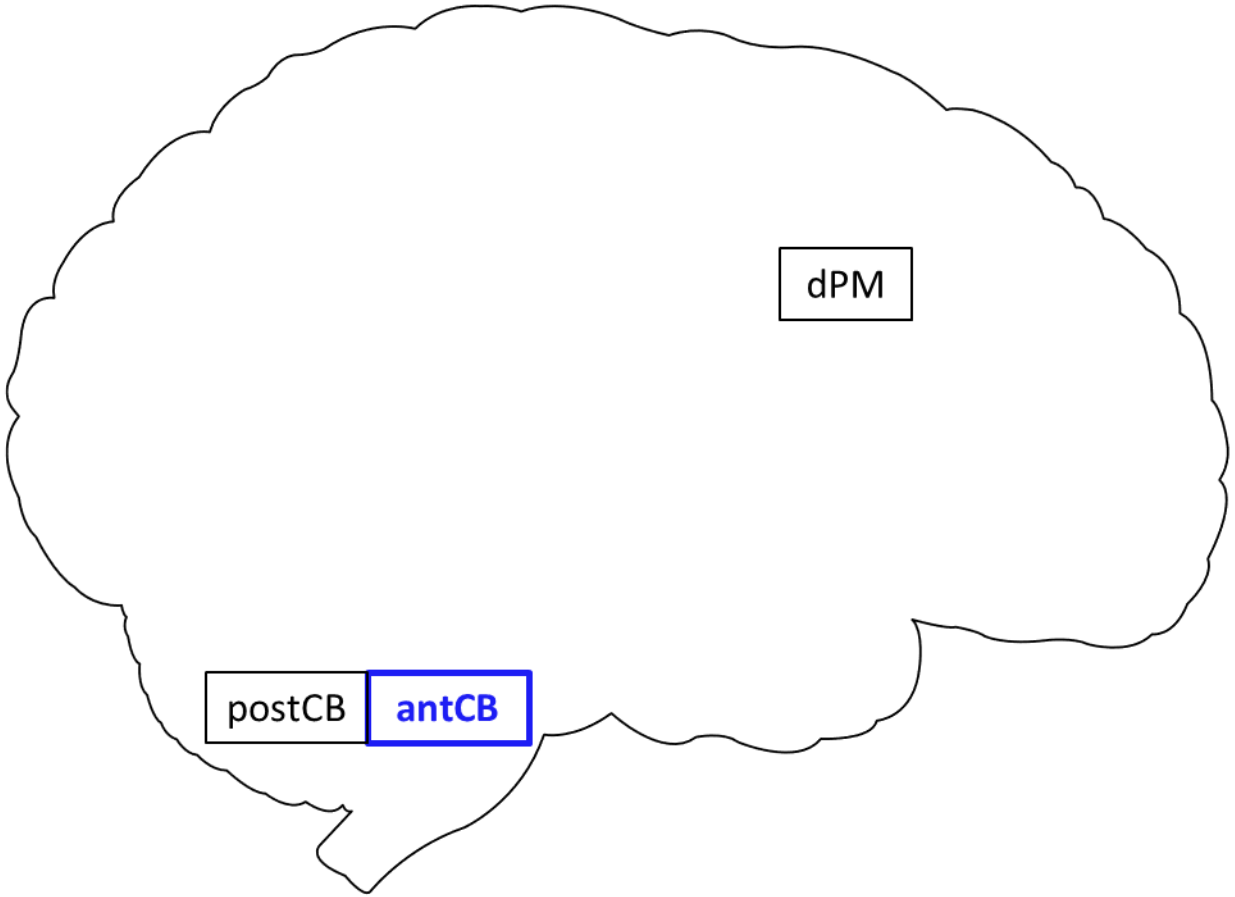
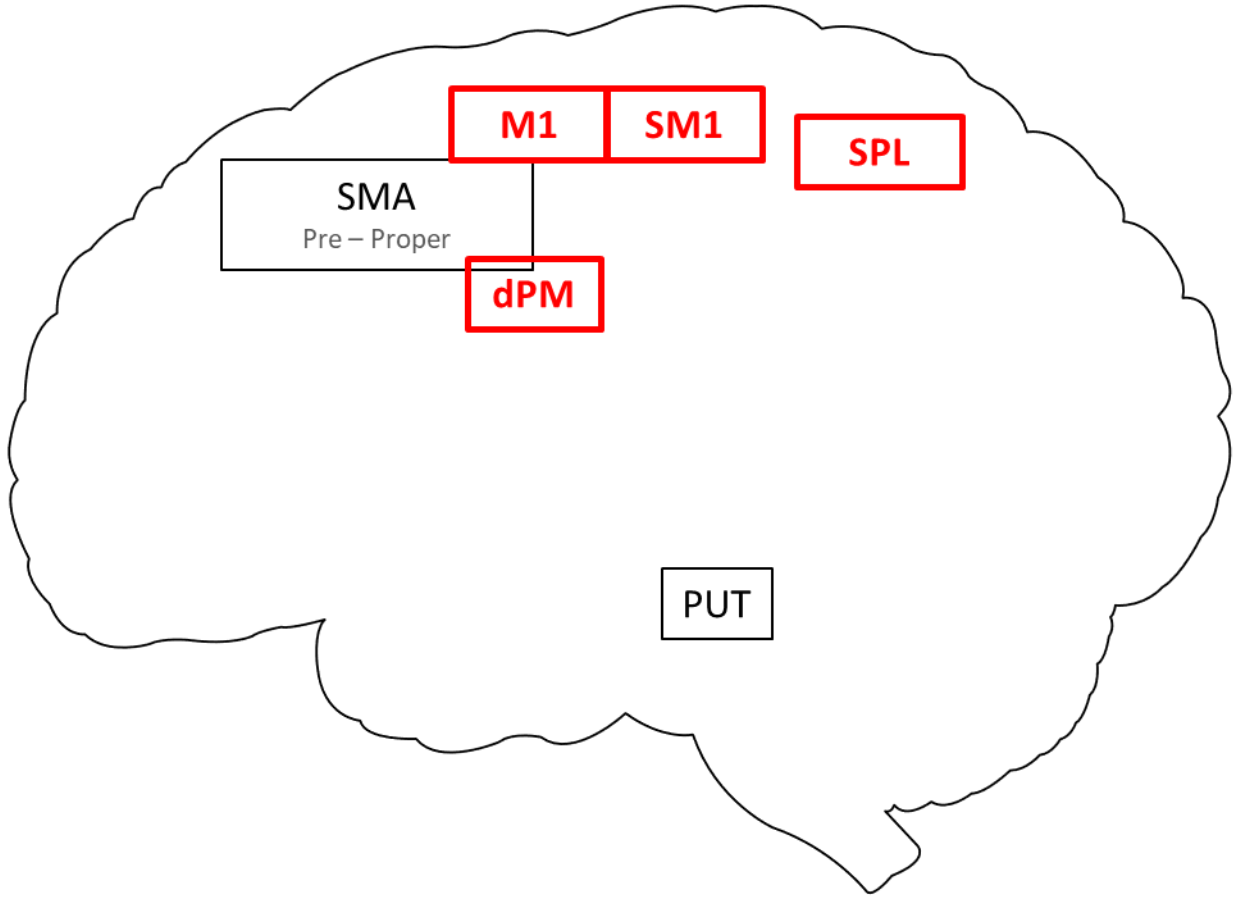


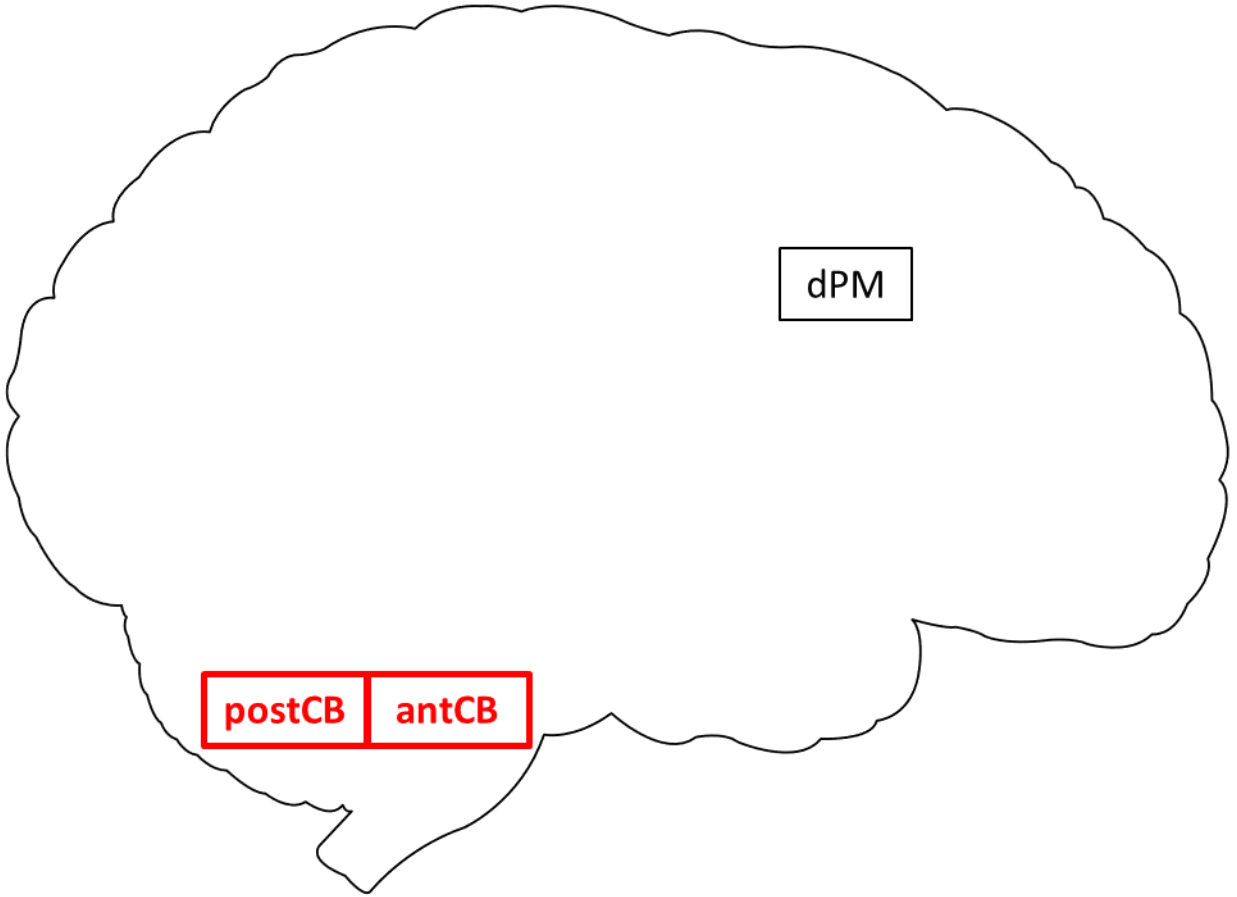
H1: Effect of sequential complexity



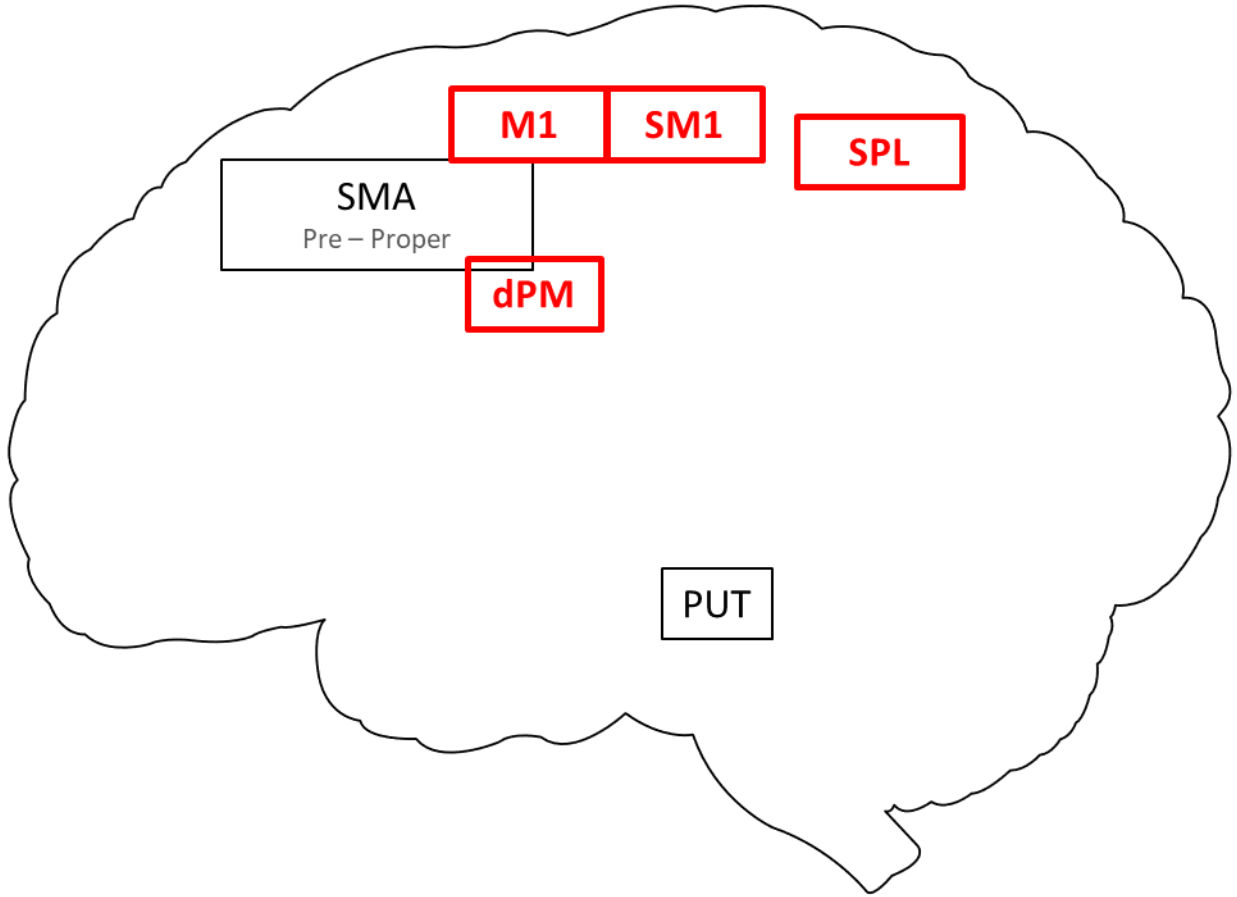
The motor network in the « handwriting brain »

H2: Effect of motor adaptation





The motor network in the « handwriting brain »



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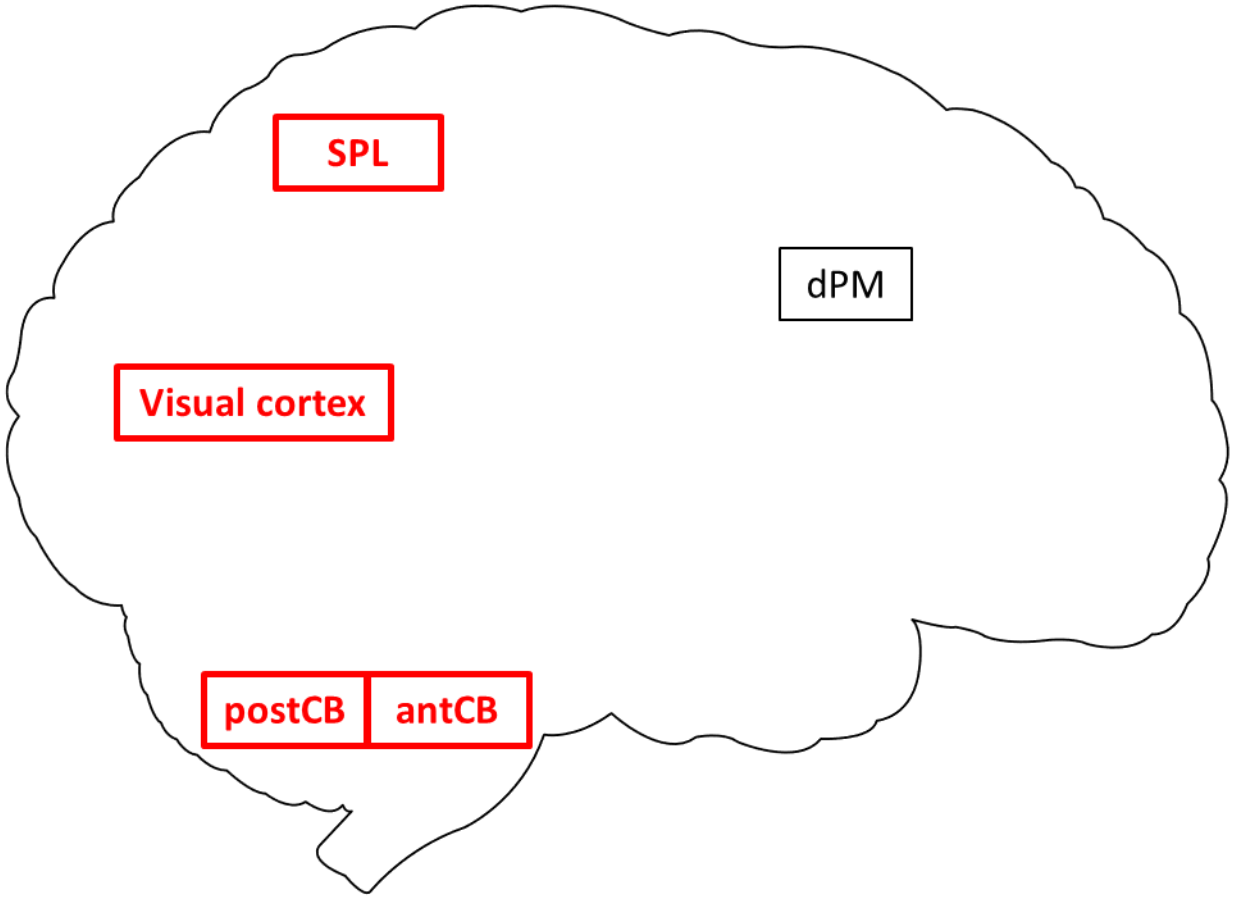


Method

Participants :

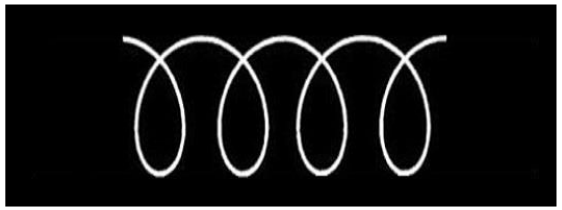
- 25 young adults (m=25,08 ± 4,41 ; 13 F), right-handed

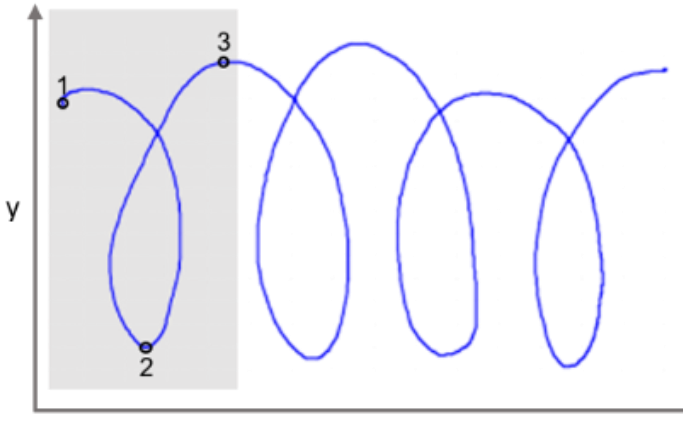
Experiment

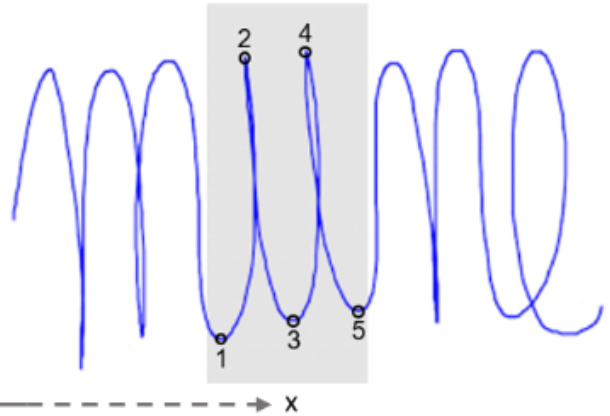
- Study explanation and consents signature;
- Administration of MoCA for cognitive assessment;
- BHK test and handwriting recording with ecological posture (pre-experiment) on a graphic tablet;

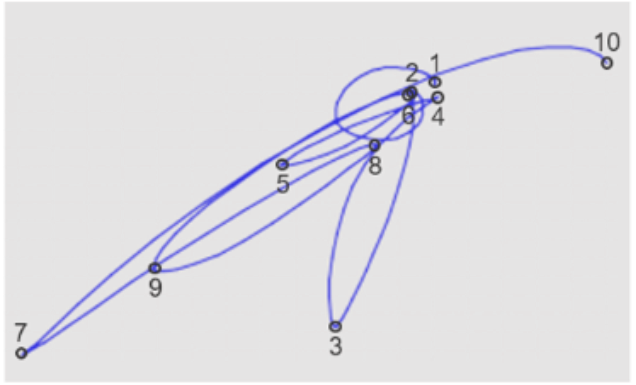
Method : behavioural pre-experiment

- Factorial Design
  - Factor « motor sequence »









Method : behavioural pre-experiment

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  - Factor « motor sequence »
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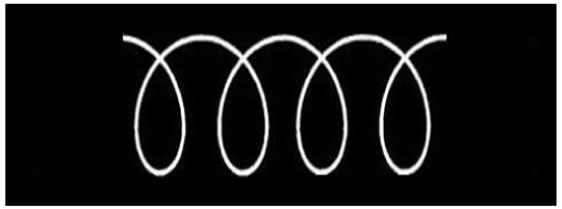
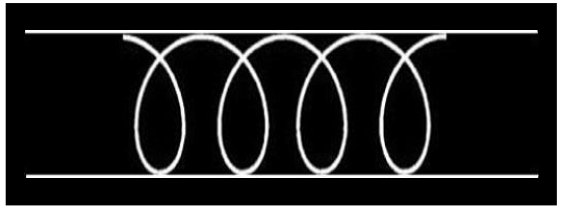




6 conditions => 3 different items x 2 spatial constraints

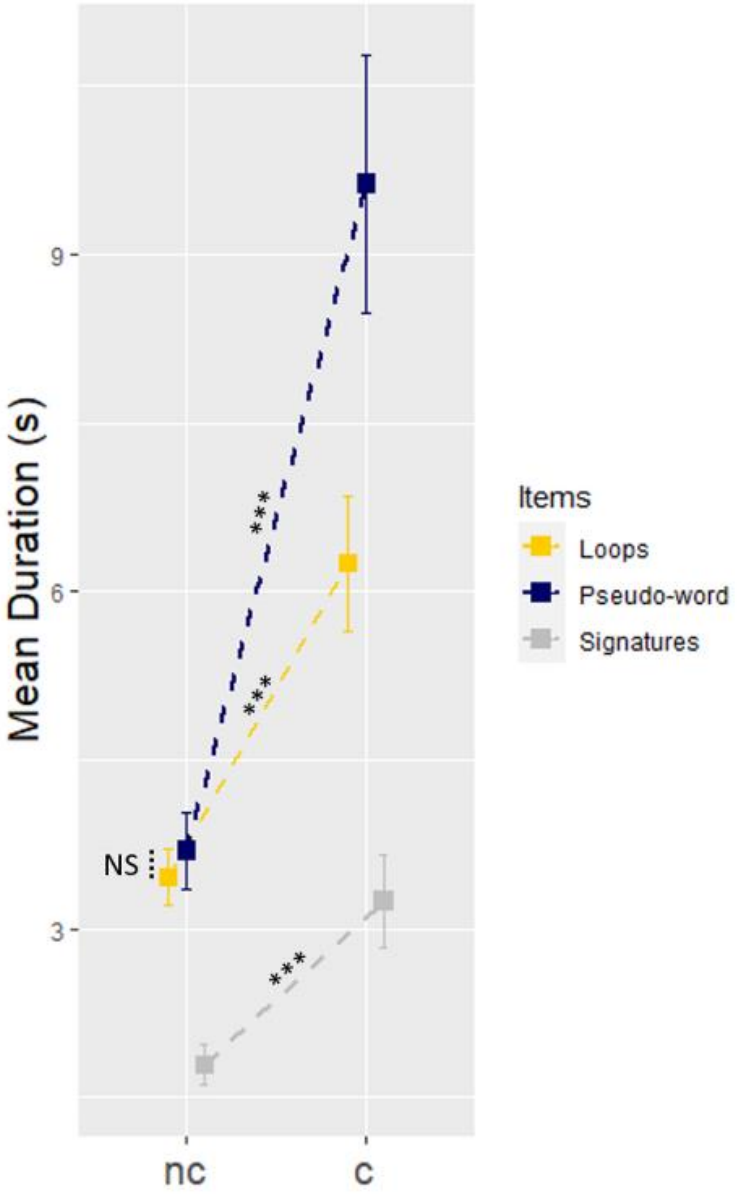
Method : behavioural pre-experiment

- Writing data analysis
  - Mean duration (s)
  - Mean writing height (mm)
  - Mean writing frequency (Hz)
  - Mean movement dysfluency (nomber of abnormal velocity peaks : SNvpd)

Results

Pre-experiment

- Main effect of item
  Signature < Pseudoword = Loops
- Main effect of spatial constraint
  Increase of writing duration
- Interaction
  Larger effect of spatial constraint for pseudo-word



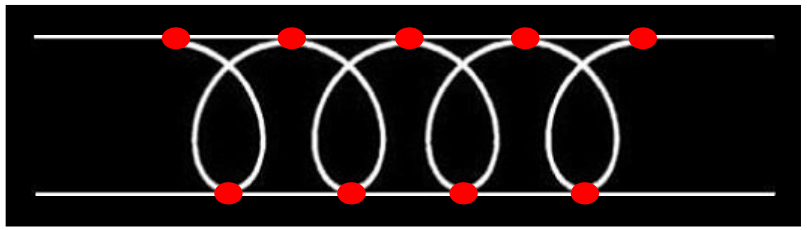
➔ Need for stroke level analysis

Results

Pre-experiment

- Without constraint, difference between the three items
  ➔ Signature > Pseudoword > Loops

- Effect of spatial constraint on the three items
  ➔ Pseudoword > Loops > Signature (no expected!)

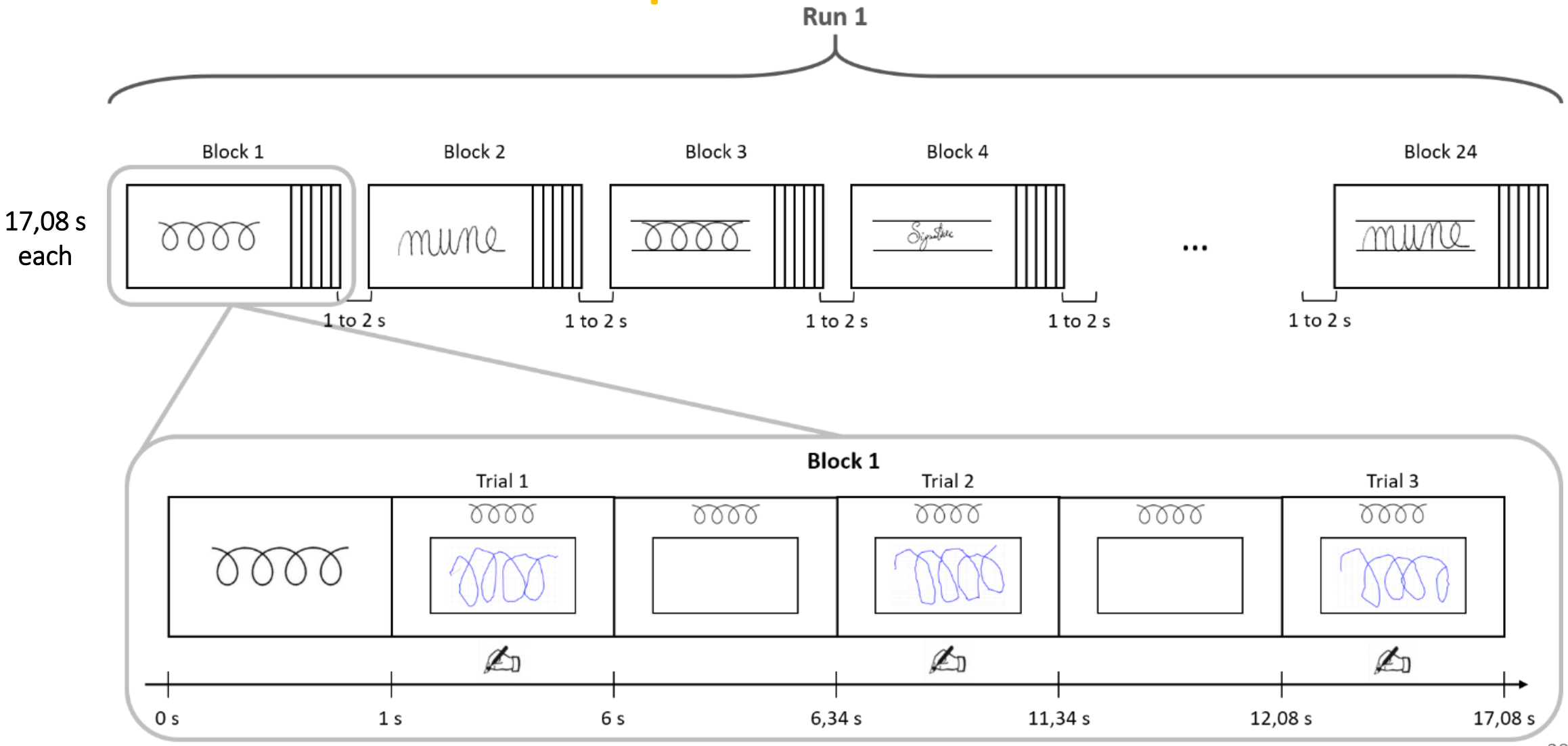


Method

fMRI Experiment

- Task training (MOCK) & fMRI (1 hour) including:
  - Run 1 (9 min)
  - Run 2 (9 min)
  - Anat 3DT1 (Compress Sensing) and 3DT2 (caipirinha) (5 min)
  - Run 3 (9 min)
  - Run 4 (9 min)

Method : fMRI experiment



Results

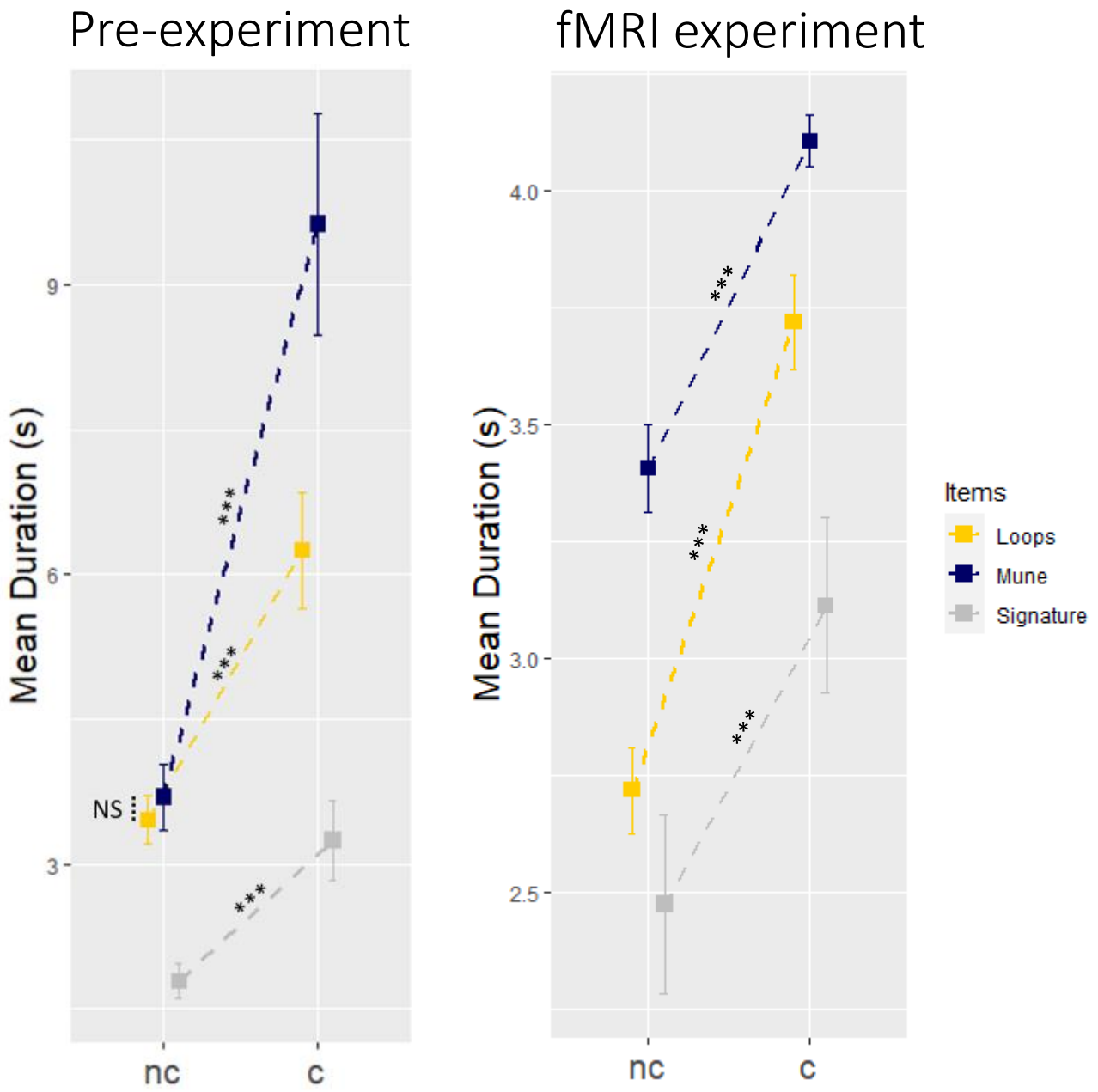
- Behaviour in fMRI

- Main effect of item
  Signature < Loops < Pseudo-word

- Main effect of spatial constraint
  Increase of writing duration

- Interaction
  No difference of duration between loops and signature without spatial constraint

- Supplementary temporal constraint in fMRI:
  ➔ Items with constraint are realised faster in fMRI



Results

- Behaviour in fMRI

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  No difference of duration between loops and signature without spatial constraint

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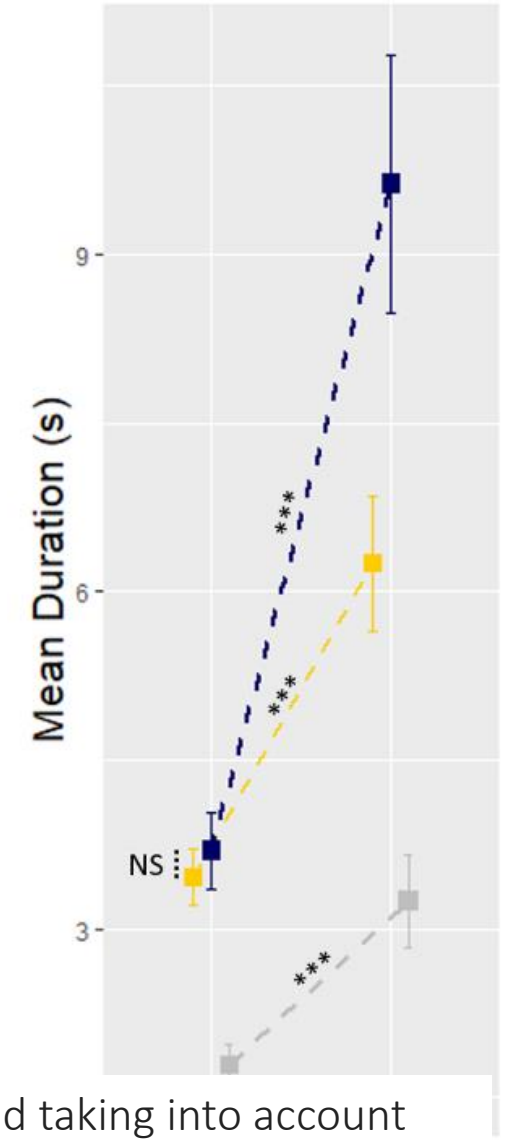
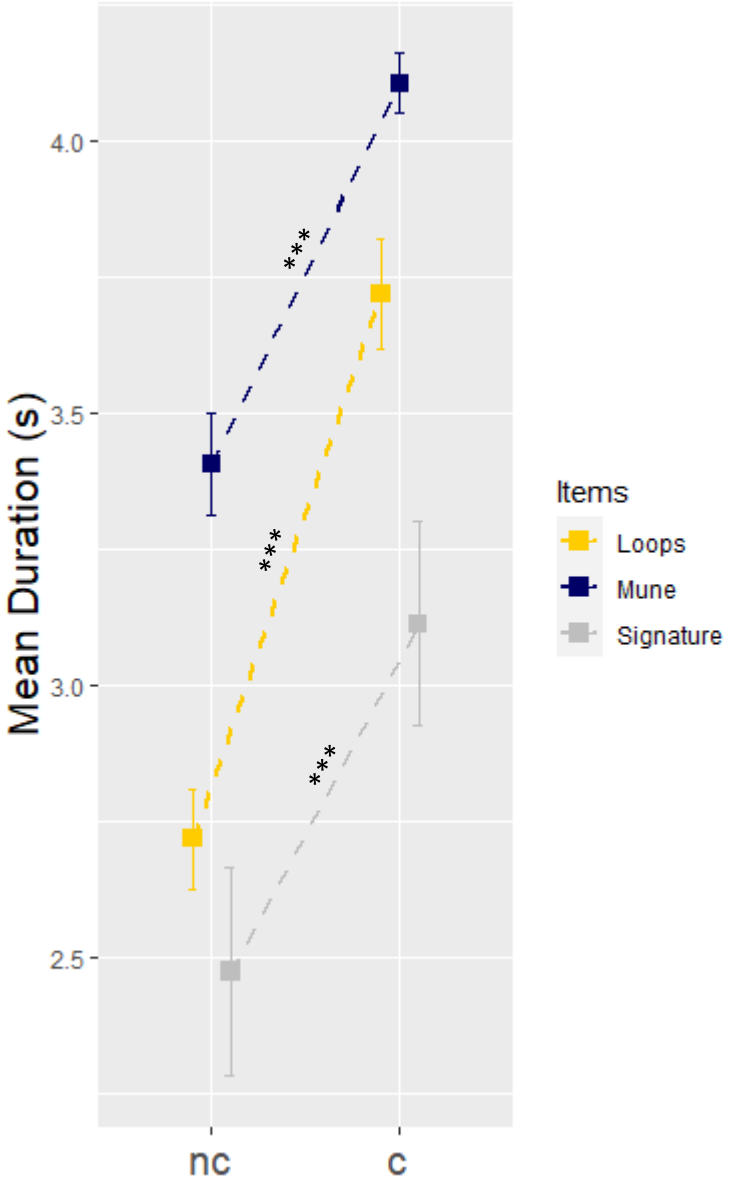
Pre-experiment



fMRI experiment

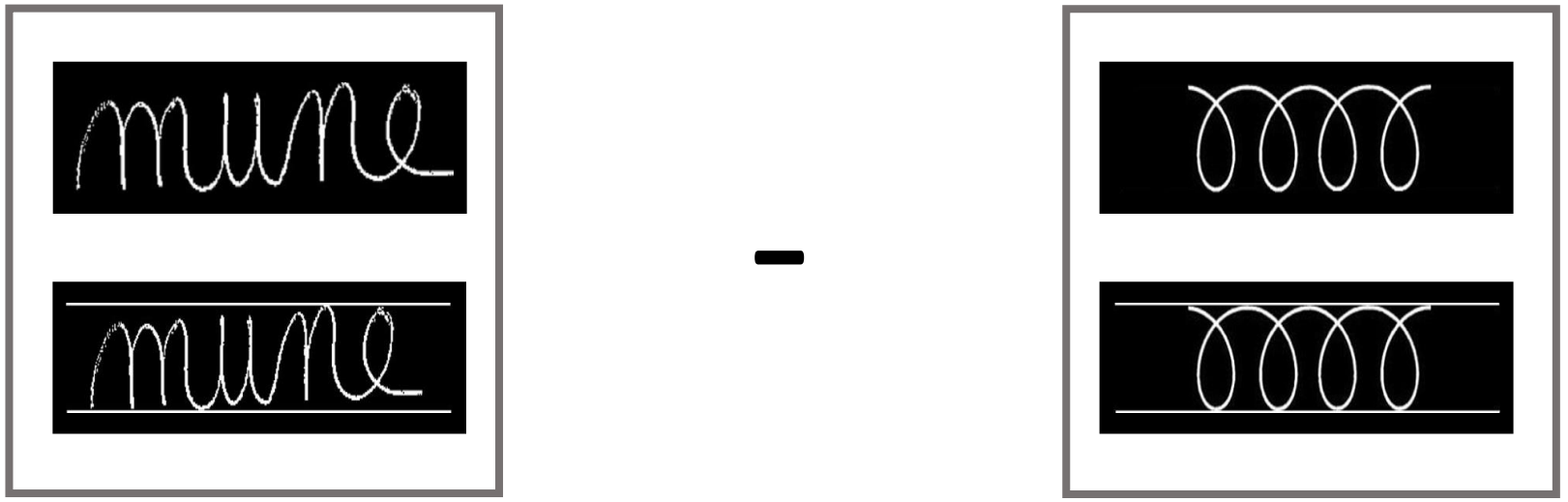


➔ a "writing" condition was modelled in the same way and taking into account the exact starts and durations of each trial of the six main conditions

Method : fMRI experiment

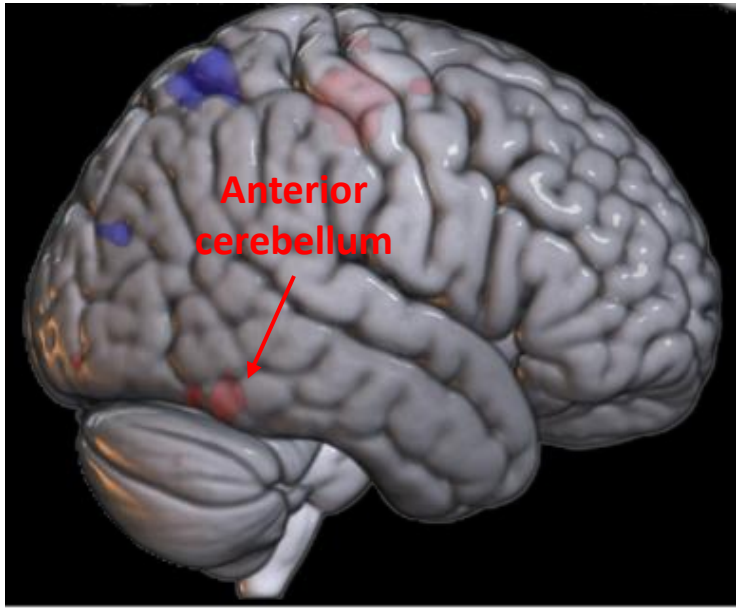
Whole brain analysis :

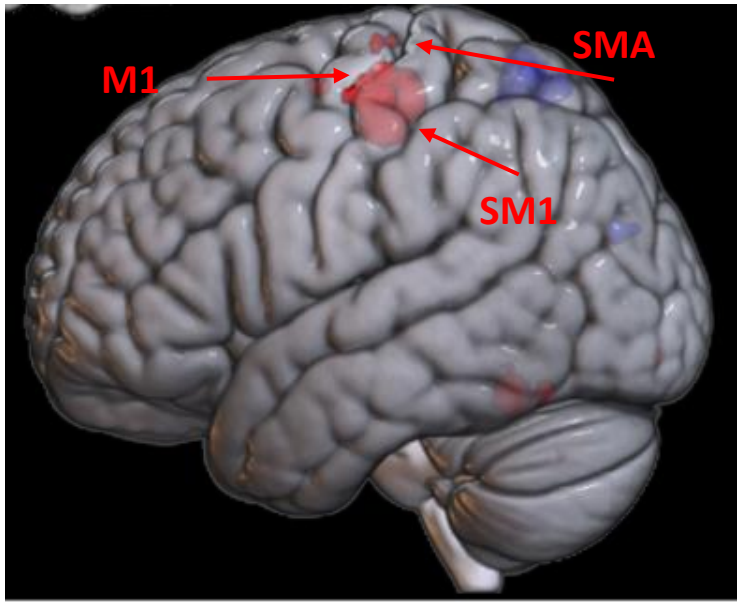
1) the main effect of item (independently of the spatial constraint):



Results

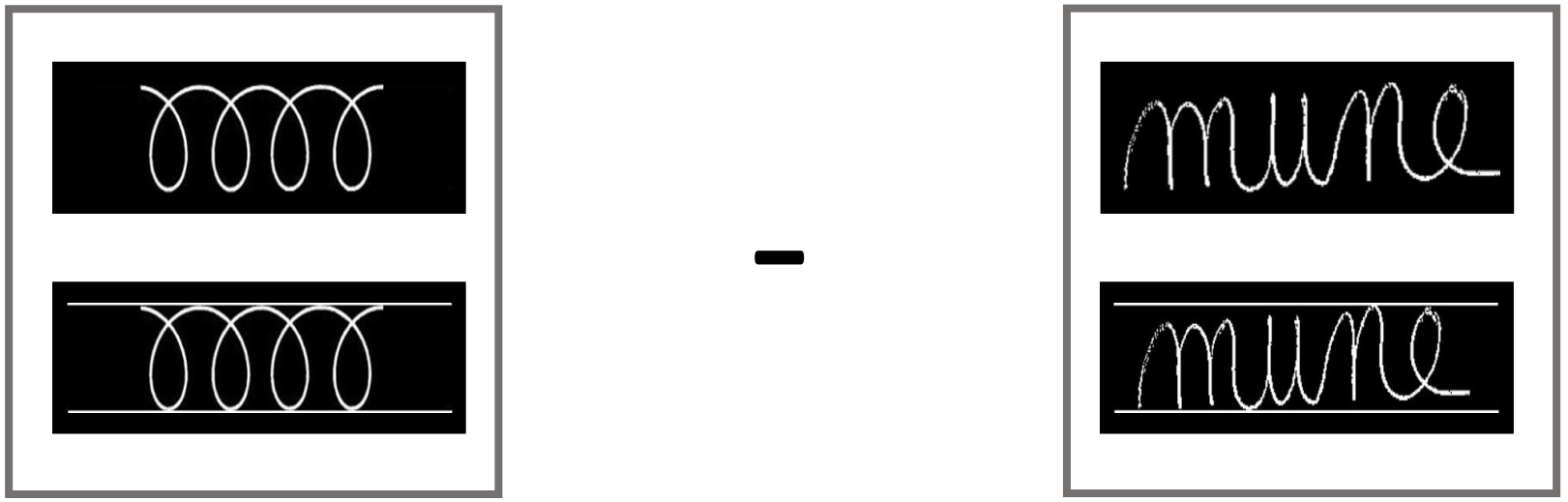
Location		Cluster size	% Cluster	Stats, t-value	MNI Coordinates x	y	z
[pseudo-word$_{nc}$+pseudo-word$_{c}$] - [loops$_{nc}$+loops$_{c}$]							
Frontal							
Left	**Precentral**	**243**	**66.67**	**11.05**	**-35**	**-24**	**56**
	Postcentral		31.69				
Left	**Supplementary motor area**	**10**	**100**	**7.54**	**-3**	**-6**	**61**
Cerebellum							
Right	**Cerebellum (IV,V)**	**40**	**67.5**	**8.92**	**18**	**-56**	**-20**
	Cerebellum (VI)		32.5				
Right	**Vermis 6**	**10**	**80**	**7.62**	**3**	**-64**	**-17**
	Vermis 4, 5		20				





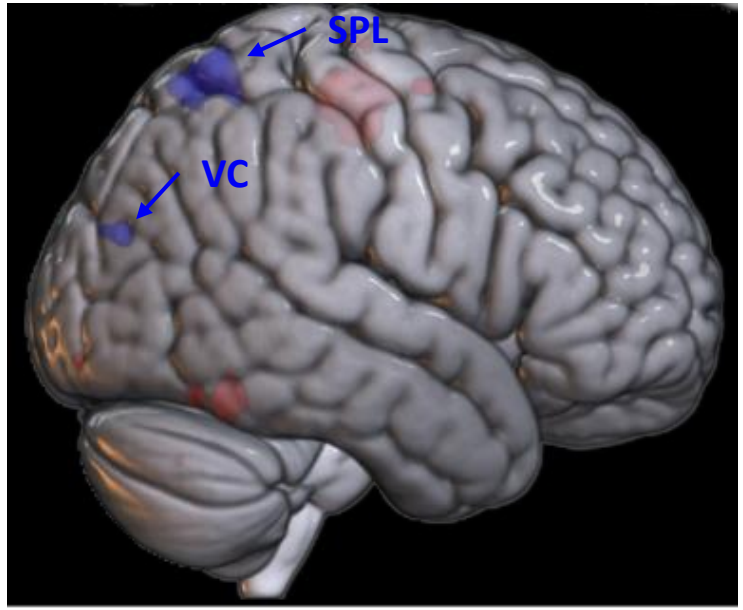
Method : fMRI experiment

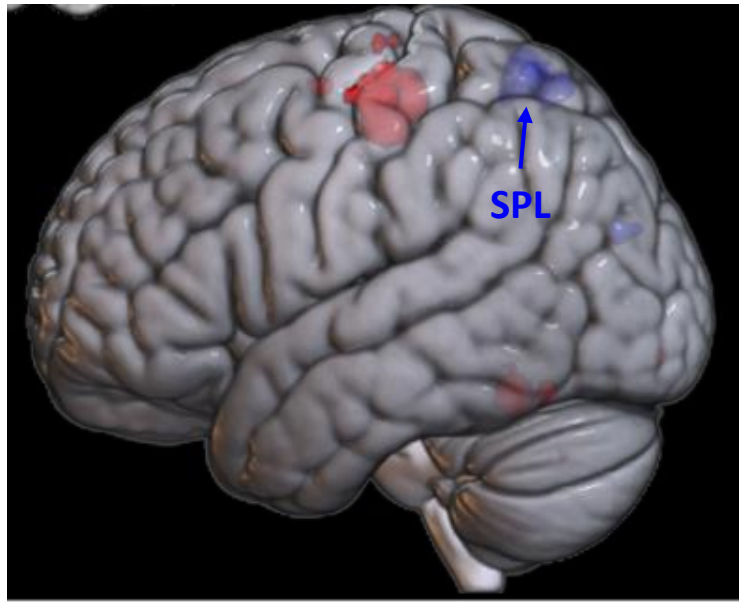
1) the main effect of item (independently of the spatial constraint):



Results

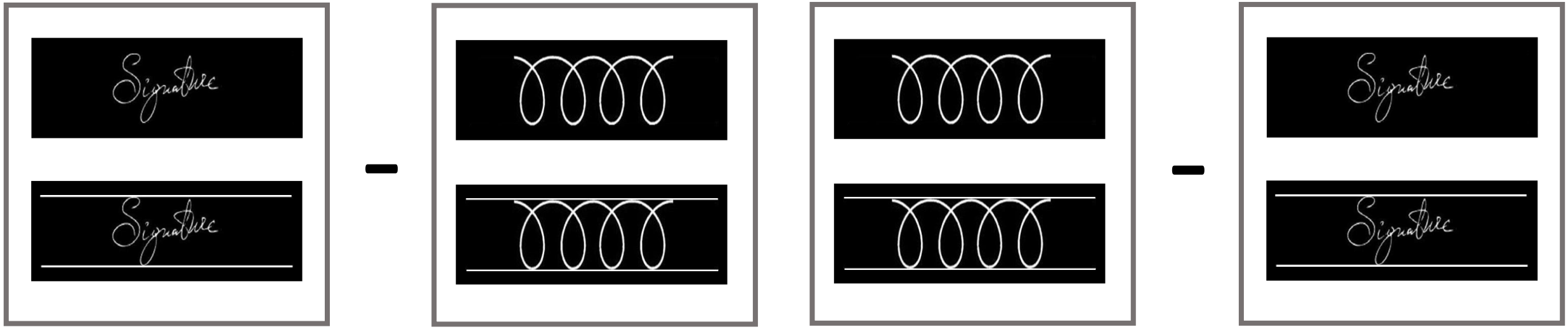
[loops$_{nc}$+loops$_{c}$] - [pseudo-word$_{nc}$+pseudo-word$_{c}$]							
Parietal							
Right	**Superior parietal area**	**136**	**80.15**	**10.70**	**18**	**-56**	**63**
	Precuneus		18.38				
Left	**Superior parietal area**	**24**	**91.67**	**7.70**	**-18**	**-61**	**63**
	Precuneus		8.33				
Occipital							
Right	**Middle occipital area**	**21**	**61.90**	**9.01**	**30**	**-81**	**23**
	Superior occipital area		38.10				





Method : fMRI experiment

1) the main effect of item (independently of the spatial constraint) :



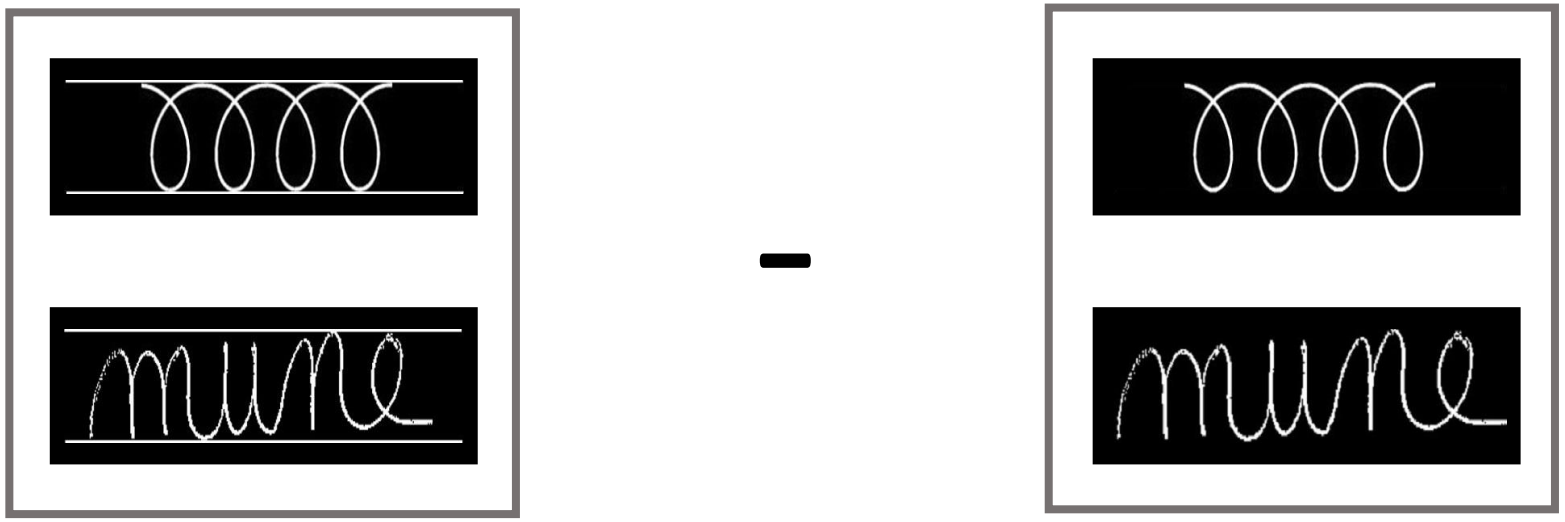
Results

1) the main effect of item (independently of the spatial constraint) :

$[signature_{nc}+signature_{c}] - [loops_{nc}+loops_{c}]$
NS at FWE threshold cluster > 9 voxels
$[loops_{nc}+loops_{c}] - [signature_{nc}+signature_{c}]$
NS at FWE threshold cluster > 9 voxels

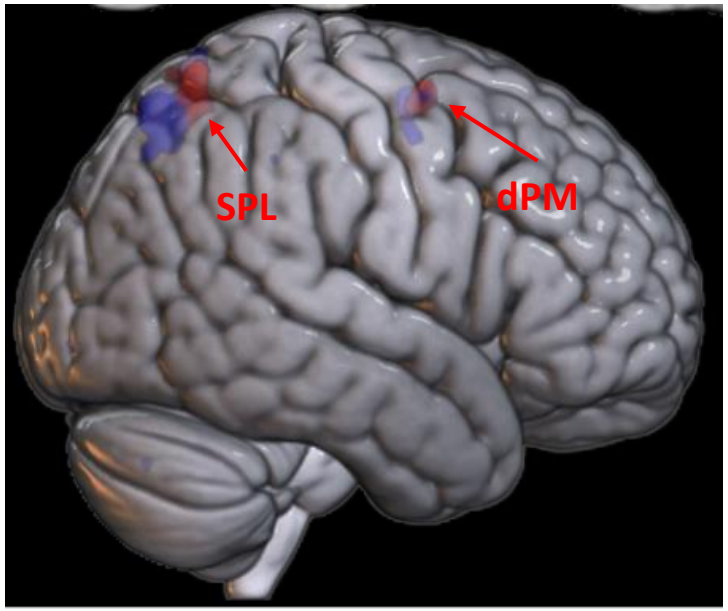
Method : fMRI experiment

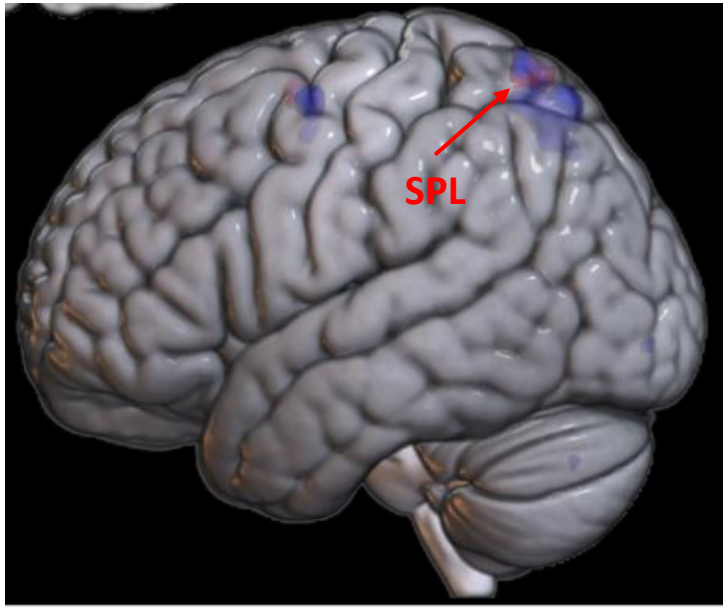
2) the main effect of spatial constraint (independently of items) :



Results

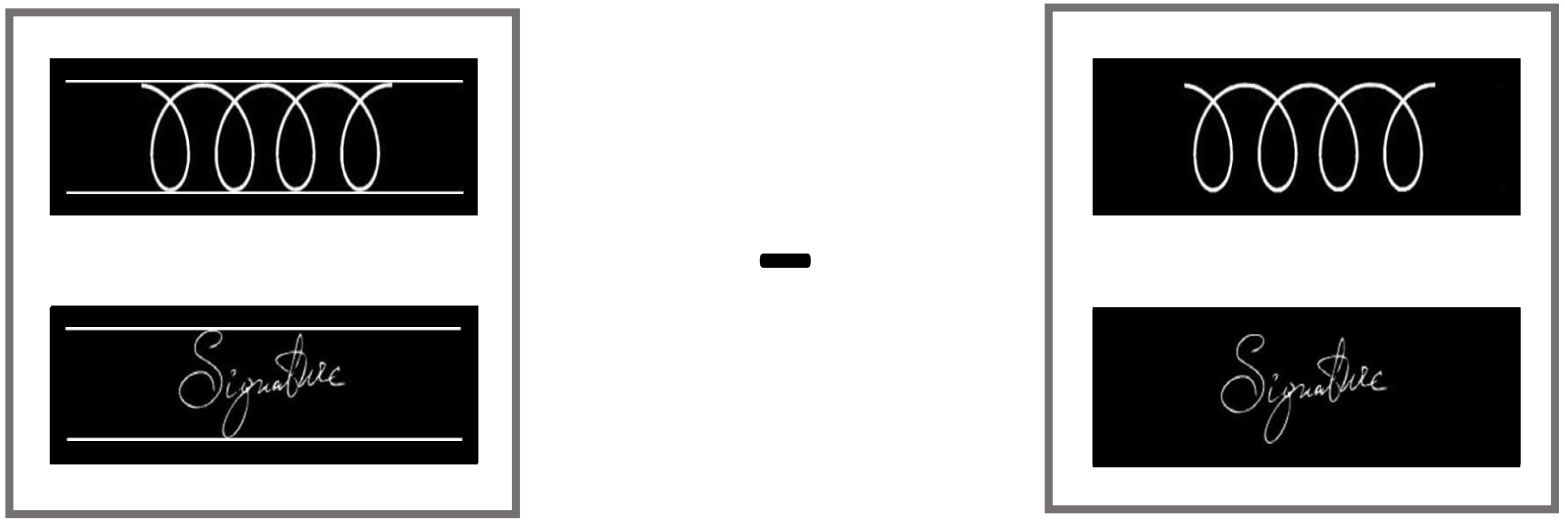
Location		Cluster size	% Cluster	Stats, t-value	MNI Coordinates x	y	z
[pseudo-word$_c$ +loops$_c$] - [pseudo-word$_{nc}$+loops$_{nc}$]							
Frontal							
Right	**Superior frontal area**	**21**	**90.48**	**8.45**	**25**	**2**	**61**
Parietal							
Left	**Superior parietal area**	**65**	**67.69**	**10.69**	**-20**	**-59**	**66**
	Precuneus		32.31				
Right	**Superior parietal area**	**83**	**97.59**	**9.22**	**20**	**-64**	**53**
	Precuneus		2.41				





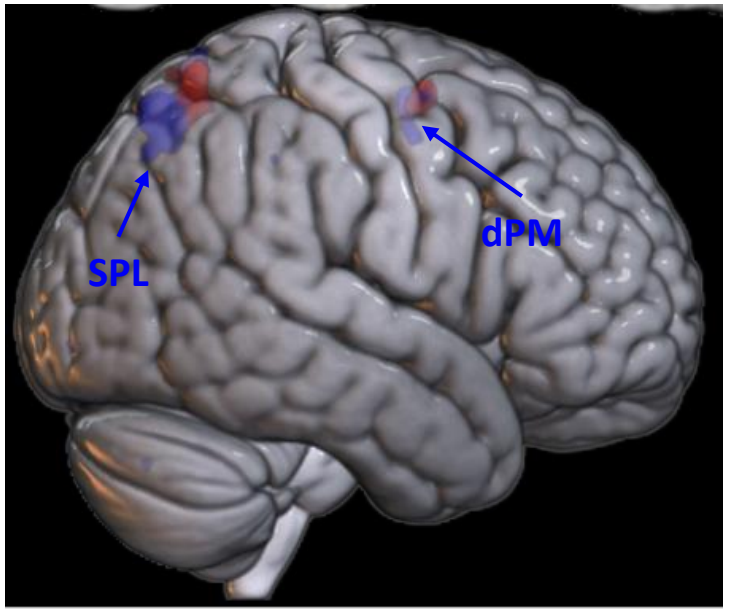
Method : fMRI experiment

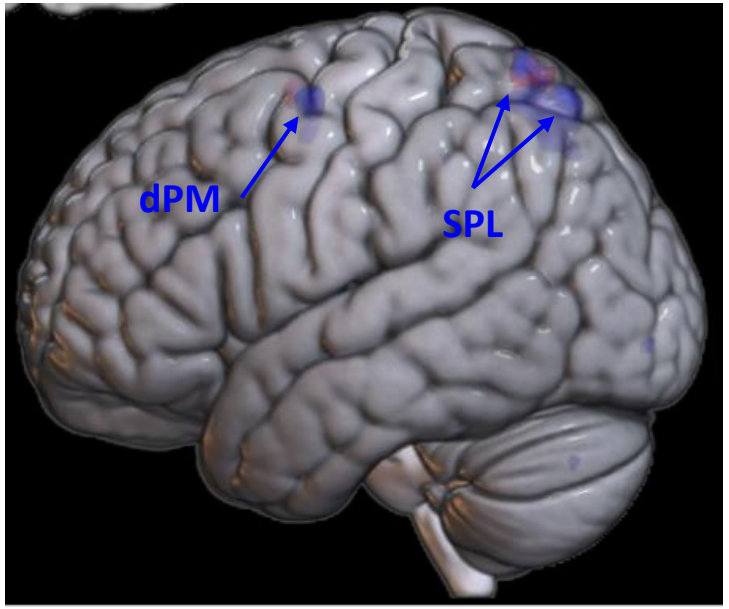
2) the main effect of spatial constraint (independently of items) :



Results

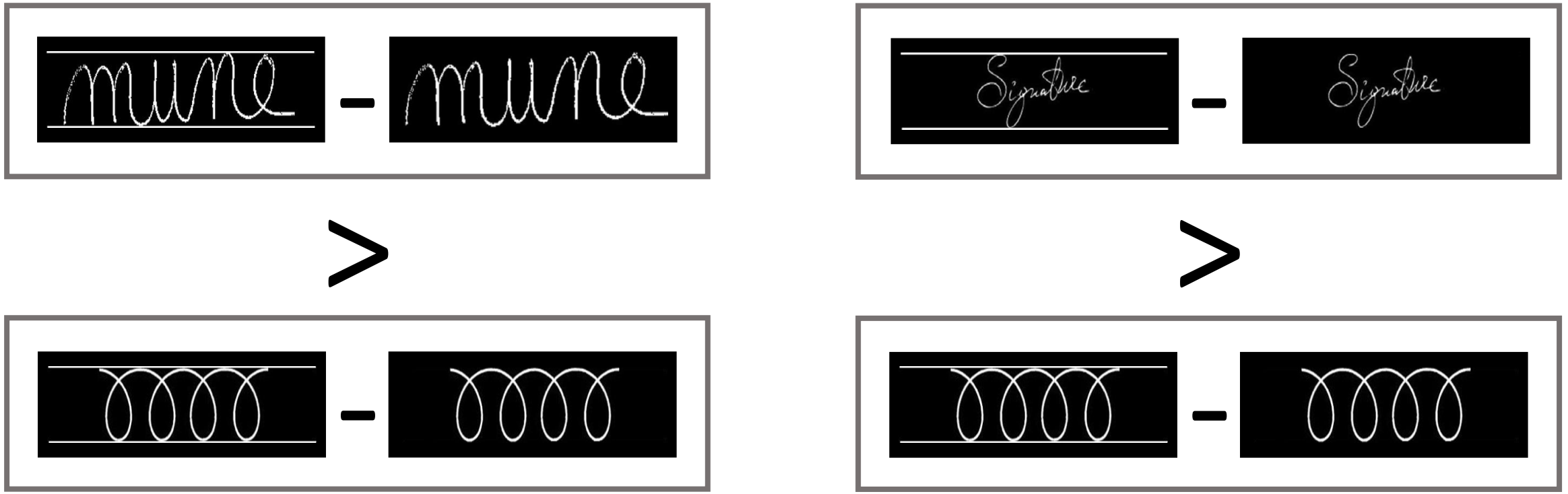
[signature$_c$ +loops$_c$] - [signature$_{nc}$+loops$_{nc}$]							
Frontal							
Left	**Superior frontal area**	**21**	**90.48**	**10.55**	**-20**	**-4**	**58**
	Middle frontal area		9.52				
Right	**Superior frontal area**	**23**	**60.87**	**7.62**	**25**	**-4**	**51**
	Middle frontal area		4.35				
	Precentral		4.35				
Parietal							
Left	**Superior parietal area**	**48**	**60.42**	**10.36**	**-20**	**-59**	**66**
	Precuneus		39.58				
Right	**Superior parietal area**	**113**	**79.65**	**9.70**	**20**	**-69**	**51**
	Superior occipital area		14.16				
	Precuneus		6.19				
Left	**Superior parietal area**	**23**	**60.87**	**9.26**	**-15**	**-69**	**58**
	Precuneus		39.13				





Method : fMRI experiment

3) the item by spatial constraint interaction:



Results

3) the interaction between item and spatial constraint factors:

Location	Cluster size	% Cluster	Stats, t-value	MNI Coordinates x	y	z
[pseudo-word$_c$-loops$_c$] - [pseudo-word$_{nc}$-loops$_{nc}$]						
NS at FWE threshold cluster > 9 voxels						
[loops$_c$-pseudo-word$_c$] - [loops$_{nc}$-pseudo-word$_{nc}$]						
NS at FWE threshold cluster > 9 voxels						
[signature$_c$-loops$_c$] - [signature$_{nc}$-loops$_{nc}$]						
NS at FWE threshold cluster > 9 voxels						
[loops$_c$-signature$_c$] - [loops$_{nc}$-signature$_{nc}$]						
NS at FWE threshold cluster > 9 voxels						

Discussion

H1: Effect of sequential complexity

- Dorsal premotor cortex

➔Would not be an interface between grapheme and motor representations of letters (Roux et al., 2009)

➔But a region associated with the storage of motor information related to the formation of graphic patterns

- SMA

➔increased role of the SMA in controlling automated writing movements (Debaere et al., 2003; Jenkins et al., 2000)

➔different degree of familiarity between the pseudoword and the loops

Discussion

H1: Effect of sequential complexity

- Superior parietal lobule

➔ Greater and bilateral activation for loops than for pseudoword

- Anterior cerebellum

➔More significant activation for the pseudoword than for the loops

➔Switch to retroactive control due to lying position in MRI

- pseudoword ➔ somatosensorial control with cerebellum and SM1
- loops ➔ visuo-spatial control with VC and SPL

Discussion

H2: Effect of motor adaptation

- Dorsal premotor cortex

➔Greater activation of right dPM with spatial constraint for pseudoword and signature

// Involved in less automated control process (Wu et al., 2016 ; Nackaerts et al., 2018; Planton et al., 2017)

- Superior parietal lobule

➔ Bilateral activation with spatial constraint

// Role of sensorimotor interface (Buneo & Andersen, 2006)

On-line control process via real-time integration of motor information

Discussion

H2: Effect of motor adaptation

- Cerebellum and visual cortex

➔ // Gowen & Mial, 2007 ; Nackaerts et al., 2018

The role not only dependent of the spatial constraint but also of the task

➔ Unexpectidely, spatial constraint does not lead to increased activation (require further analyses)

Discussion

- Further analyses required ?
  - Global analysis?
  - Analysis by items?
  - MVPA ?
  - Dynamic Causal Modeling?

Merci pour votre attention