Multilingualism and Cognitive Control

The language switching hypothesis

Xavier Aparicio, PhD

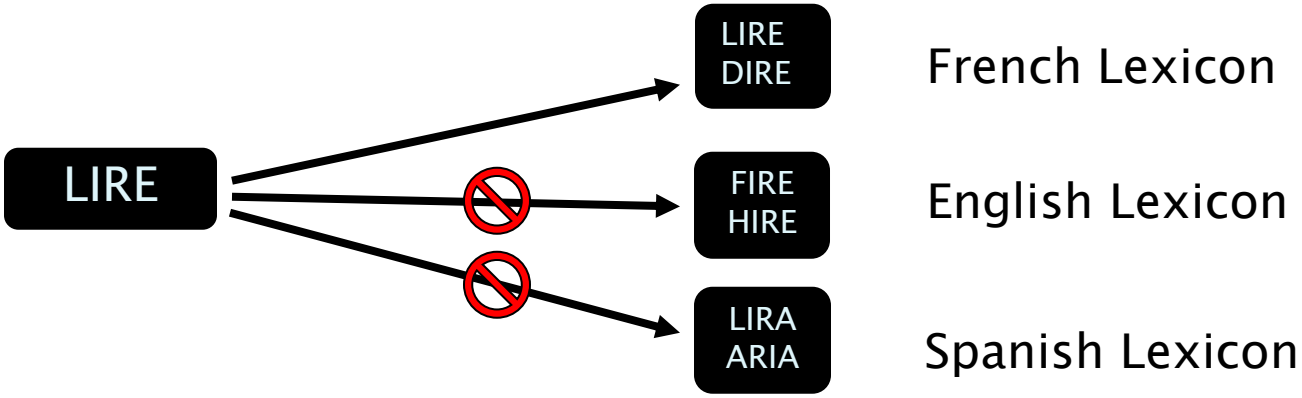
Workshop « Language Control in second language learners », Toulouse, 18th June 2014

The multilingual lexicon

- Part of human memory (Dijkstra 2005)
- Interplay between several information
  - Orthographics
  - Phonology
  - Syntaxic
  - Semantics
  - Languages (for multilinguals)

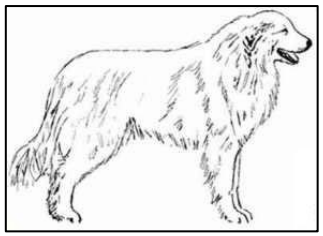
Lexical access

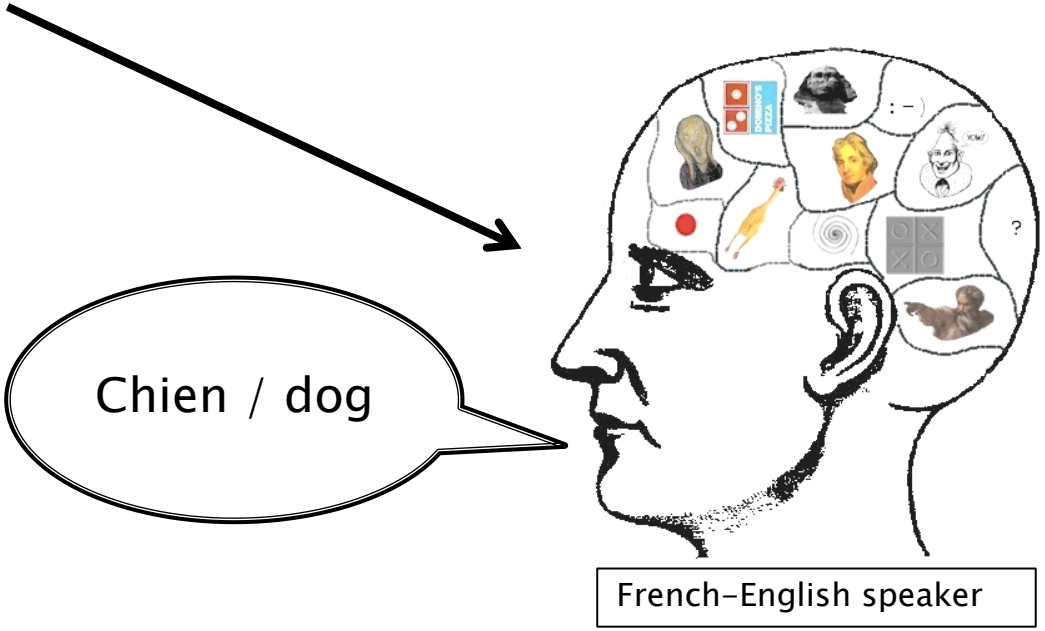
- Language selective (Gerard & Scarborough, 1989)



- Language non-selective: Organized by features (Dijkstra, Van Jaarsveld & Ten Brinke, 1998)

Language activation





- A bilingual is a kind of juggler : both languages are active regardless of the requirement to use one language alone
- Parallel activation and competition in listening, reading and speaking

Language switching

- Multilinguals switch (with a relative ease) between languages.
- Allow to keep the meaning during a conversation (flexibility).
- Modulated by language proficiency, semantic and orthographic overlap
- Require control processes as well as inhibition mechanisms ➔ active top-down inhibition mechanism applied on the irrelevant language (BIA and IC models)

Models

- Bilingual Interactive Activation Model (BIA, Grainger & Dijkstra, 1992) :
  - Lower resting level of activation for L2 = slower recognition
  - Top-down inhibition of lexical candidates

- Inhibitory Control (Green, 1998)
  - Language tasks schemas
  - Conceptualize builds the representation
  - Language tasks schema compete to control output by altering levels of activation and inhibiting other schemas.

- Revised Hierarchical Model (Kroll & Stewart, 1994)
  - Two language-specific lexicons and a common conceptual store
  - Tranlation equivalents maps into the same conceptual node
  - Faster translation from L2 to L1 than L1 to L2, due to strongest direct links

Language Switching effects

- Largely demonstrated in naming (e.g. Costa & Santesteban, 2004) with asymmetrical effects in consecutive bilinguals (L1→L2 < L2→ L1)

- Early switch: masked translation priming (Aparicio & Lavaur, submitted; Chauncey et al., 2008; Dimitropoulou et al., 2011 a et b)
  - Higher processing costs in all between between language conditions than in within language conditions

Language Switching effects

- Large evidence of a cost associated with language switching in bilinguals using lexical decision tasks (Chauncey et al., 2008; Grainger & Beauvillain , 1987; Thomas & Allport, 2000).
  - Slower RTs in lists with languages mixed in comparison with monolingual lists ➔ due to language switching ; asymmetrical switch costs (e.g. Grainger & Beauvillain, 1987)
  - ➔ automacity of L1 and overcoming of inhibition.
  - Symmetrical switch cost for early proficient bilinguals
  - Language information relative to target word is processed even if it is not relevant to perform the task.

Language switching and control

- Switching between languages creates a need to negotiate competition across languages so that the use of each language is controlled to enable **fluent performance;**

- These control processes may include inhibition of the L1 or more dominant language with enduring consequences for native language use.

- Skill in resolving cross-language competition is hypothesized to create expertise that affects cognition and the brain.

Language switching and control

- The models suggests that lexical candidates have to be inhibited so that only the relevant target word remains activated → Link to executive control functions (Calabria et al., 2012; Green & Abutalebi, 2013).

- Language control processes fully subsidiary to domain-general executive control functioning
  - same set of executive control processes involved in non-linguistic activities requiring executive control.
  - Language switching = same control mechanisms as switch between non-linguistic tasks

- Language control partially subsidiary to domain-general executive control = benefits due to processes specific to languages.
  - Additional processes required for language switch = permanent cross-talk between language and domain-general control processes

➔ Importance of age of acquisition and proficiency (Garbin & al., 2011)

Adaptative Control Hypothesis

- Increase in language control shared with domain-general processes (Green & Abutalebi, 2013).
  - Language control processes adapt to the recurrent demands placed on them by the interactional context (single language, dual language or dense code-switching)

	Interactional contexts		
Control processes	*Single language*	*Dual language*	*Dense code-switching*
Goal maintenance	+	**+**	=
Interference control: conflict monitoring and interference suppression	+	**+**	=
Salient cue detection	=	**+**	=
Selective response inhibition	=	**+**	=
Task disengagement	=	**+**	=
Task engagement	=	**+**	=
Opportunistic planning	=	=	**+**

+indicates the context increases the demand on that control process (more so if bolded); =indicates that the context is neutral in its effects. Please see main text for explanation of the control processes.

Inhibition processes

- Relevant to explain bilingual performances in terms of executive control ➔ bilingual advantage
- Multidimensional, several componants (Melcher, 2007; Mueller et al., 2009)
  - Current Inhibition = applied to automatic activities (e.g. reading, eye movements)
  - Overcoming of inhibition (overcome the inhibition previously settled on an automatic activity; the strongest is the current inhibition, the more dificult it is to overcome)
- Shared (at least partially) by domain general processes

Overview of the studies

- Experiment 1& 2: language switching mechanisms in successive trilinguals
  - Generalized lexical decision and masked translation priming

- Experiment 3 & 4: language switching influence in performance on tasks involving language control or domain-general control.
  - Language decision, bilingual Stroop task and anti-saccade tasks (monolinguals, bilinguals and Interpreters)

Experiment 1 : Language Switching effects in trilinguals

Aparicio, X., & Lavaur, J-M. (2013). Recognizing words in three languages: Effects of language dominance and language repetition. *International Journal of Multilingualism*, 11(*2*), 164-181.

- Aparicio et al. (2012): hierarchy between the three languages in successive trilinguals (larger N400 amplitude for the two non-dominant languages).
- Estimate the dominance effect between different monolingual lists baseline for each language in terms of lexical access, see Aparicio et al., 2012).
- Estimate all language switch costs combinations, including between the two non-native languages (L2 and L3).

Participants

- 18 students in Foreign Language studies.

- French native speakers with late acquisition of L2 (English) and L3 (Spanish) but relative high proficiency in these languages.

	Languages		
Language skills	LI – French	L2 – English	L3 – Spanish
Reading	6.9 (0.1)	6.2 (0.2)	5.8 (0.9)
Oral understanding	7.0 (0.0)	6.0 (0.5)	5.2 (0.6)
Speaking	7.0 (0.0)	6.0 (0.4)	5.1 (0.4)
AoA (years)	–	9.8 (1.2)	13.6 (1.0)

- Post-test of translation (L2 to L1 and L3 to L1) significantly better in English $t(17) = 4.3$, $p < .05$.

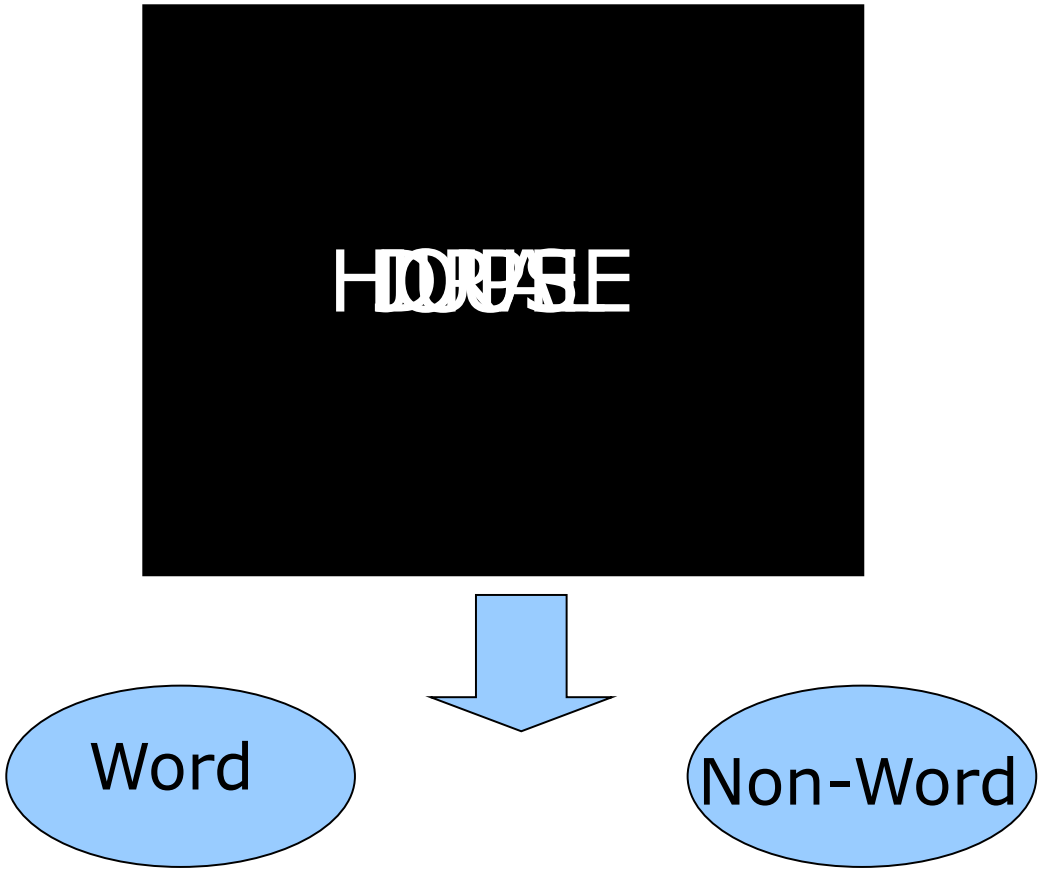
Stimuli

- 140 non cognate words per language (*e.g. maison-house-casa)*
- Each list contains 60 words and 60 non-words

Monolingual Lists			Bilingual Lists			Trilingual List
L1	L2	L3	L1 - L2	L1 - L3	L2 - L3	L1 - L2 - L3

- As many switch as repetition for bilingual and trilingual lists.

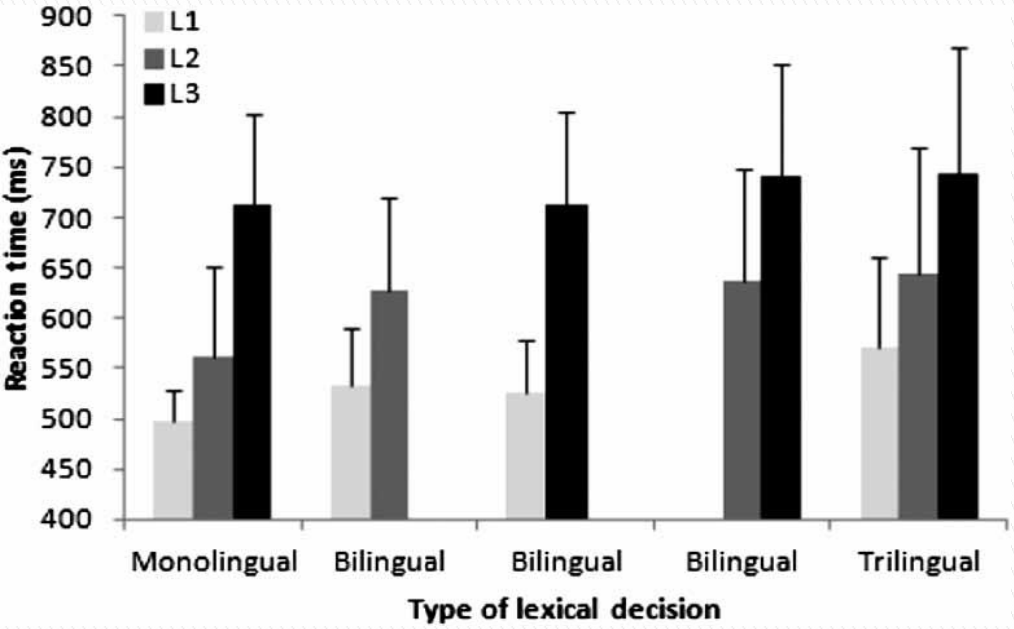
Lexical decision task



Hypotheses

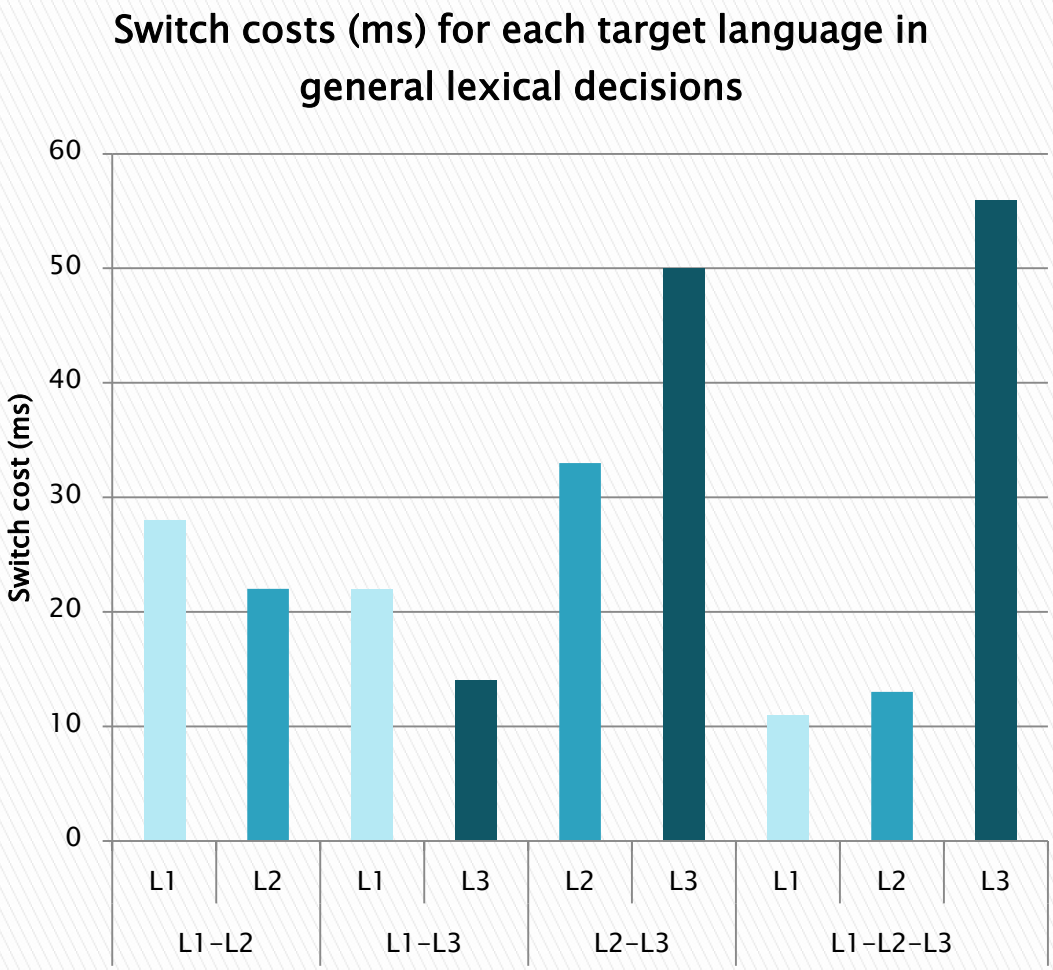
- Hierarchy in the processing of the three languages (according to AoA or dominance, see Aparicio et al., 2012).
- Slow down of processing as a function of the number of languages involved in the experimental list (monolingual<bilingual<trilingual)
- Larger switch cost in L2-L1 and L3-L1 directions
- For the two non-dominant languages, we expect larger effects for L3-L2 switching according to AoA, L3-L2 according to proficiency.

Results lexical decision



- Hierarchy verified between the three languages L1<L2<L3
- Slower Rts for all languages in bilingual and trilingual lexical decision
- Effects linked to the density of switching as well as switching directions.

Results: switch costs



- Switch cost larger for L1 in bilingual lexical decisions
- Switch cost larger for L3 when the two non-dominant languages are involved.
- Possible ceiling effect for L1 and L2 in the trilingual lexical decision
- Mediation by L1 when the two non-dominant languages are involved.

Discussion Experiment 1

- General slowdown of processing (for all languages)
- Asymmetry « partially » verified ➔ ceiling effect for L1 in the trilingual decision due to the high density of switching.
- Strongest inhibition on L1 in bilingual decisions ➔ greater control ?
- Larger switch cost for L3 = related to proficiency more than AoA.
- Necessity to investigate deeply the links between the two non-dominant languages

Experiment 2: Masked translation priming

- Asymmetry in masked translation priming studies for high proficient (but late) bilinguals (e.g. Dimitropoulou et al., 2011 a et b).
  - Consistent priming effect in forward translation direction (L1 primes and L2 targets)
  - Elusive effects in the other direction
- Priming effect modulated by the proficiency in the non-dominant language.
- Duñabeitia & al. (2010b) reported symmetric bidirectional translation priming effects with balanced simultaneous Spanish-English bilinguals.
- What about masked translation priming using both non-dominant languages as targets ?

Participants

- 24 students in Foreign Language studies.

- French native speakers with late acquisition of L2 (English) and L3 (Spanish) but relative high proficiency in these languages.

	L1 - French	L2 – English	L3 – Spanish
Writing understanding	7.0 (0.0)	5.5 (1.2)	4.6 (1.2)
Oral understanding	7.0 (0.0)	5.6 (0.5)	5.3 (0.3)
Speaking (production)	7.0 (0.0)	5.7 (1.0)	5.2 (1.0)
Age of Acquisition (in years)	---	9.9 (0.7)	12.9 (1.1)

- Post-test of translation (L2 to L1 and L3 to L1) significantly better in English $t(23) = 6.7$, $p < .05$.

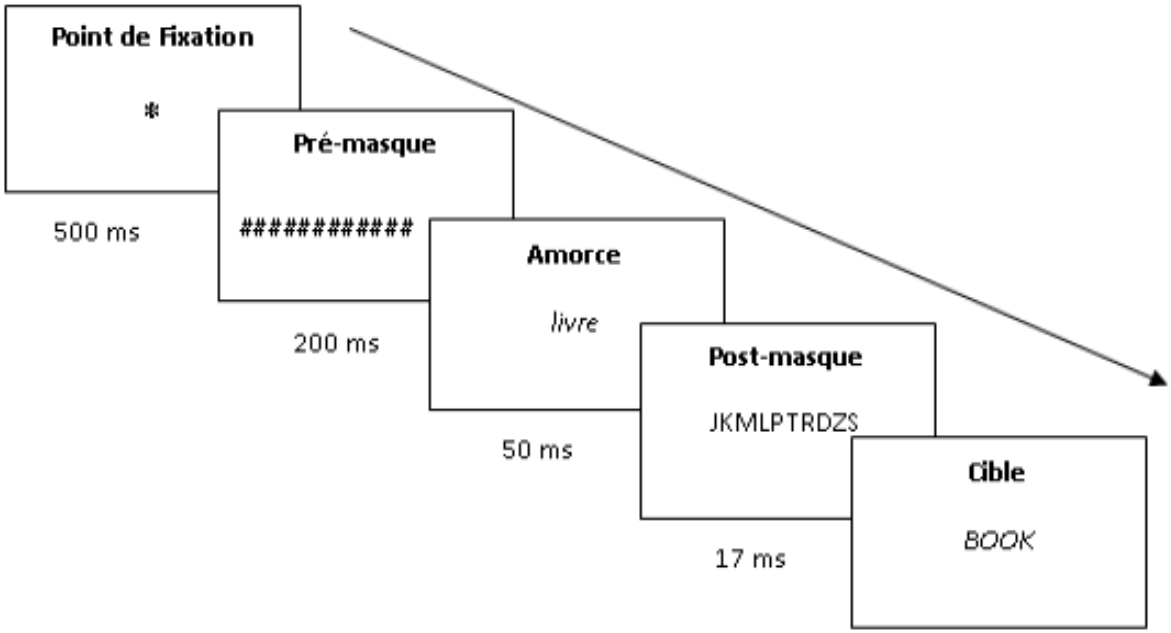
Stimuli & Procedure

- 120 non cognate words per language (*e.g. maison-house-casa)* presented as prime or target (depending on the list; 6 lists created).

- Each list contains 120 words and 120 non-words

Primes	Repetition		Translation			Unrelated		
	L2/L3	L1	L2	L3	L1	L2	L3	
Targets L2	house/HOUSE	maison/HOUSE	---	casa/HOUSE	chien/HOUSE	dog/HOUSE	perro/HOUSE	
Targets L3	casa/CASA	maison/CASA	house/CASA	---	chien/CASA	perro/CASA	dog/CASA	

- 20 items in each priming condition;



Switching in masked priming

- Difference in the RTs obtained when target are preceded by primes of the non-target language and in the RTs obtained when target words are preceded by primes belonging to the target language (e.g. Chaucey et al., 2008).

- Our design allows us to study costs of language switching at early stage of processing;

- Cost of language switching between the two non-dominant languages, which has never been done in masked translation priming studies.

Results

Targets	Priming condition															
	French (L1)				English (L2)				Spanish (L3)				Priming effect			
	Repetition		Unrelated		Repetition		Unrelated		Repetition		Unrelated		Repetition		Translation	
	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
Spanish (L3)	601,3	8,7	625,2	8,3	612,1	7,5	621,7	9,2	577,4	6,7	625	8,2	47,2	1,5	9,6	1,7
English (L2)	560,4	5,4	573,9	3,7	526,1	1,7	576,5	3,9	578,7	3,3	582	5,2	50,4	2,2	3,1	1,9

- L2 targets processed faster than L3 targets and elicit less errors.
- Repetition and translation primes elicit faster answer than unrelated primes
- Interaction between prime language and target language
  - Only significant for L1 translation primes in both L2 and L3 lexical decisions
  - Comparable magnitude of repetition and translation priming effects for L2 and L3 targets.
  - Significant within-language repetition priming effect for both languages (47.2 and 50.4 ms)

Results: Switch cost

	L2 Targets			L3 Targets	
L2 Primes	576,5	Switch Cost	L3 Primes	624,6	Switch Cost
L1 Primes	573,9	-2,6	L1 Primes	625,2	0,6
L3 Primes	581,8	5,3	L2 Primes	621,7	-2,9

- If we consider both translation priming and unrelated priming (Dimitropoulou et al., 2011), higher processing costs in between-language conditions (for L2 and L3 targets).

- No significant switch cost highlighted

Discussion Experiment 2

- Results in line with models of bilingualism (BIA and IC)
- Importance of age of acquisition (L2 targets answered faster than L3)
- Differences between translation priming and unrelated priming as well as differences in switch costs suggests early access to semantics
- In translation priming, L1 primes seems more efficient than primes from non-dominant language
- Lack of switching effects for unrelated primes ≠ Dimitropoulou et al. (2010)
  - But participants differs in terms of proficiency and spoken languages.

Discussion Experiment 2

- Greater efficiency in terms of language control (no need of overcoming of inhibition at this stage of processing)
- Semantics intervein early in masked translation priming
- Necessity to develop accurate questionnaires for a better understanding of language use by multilinguals.
- Early activation of inhibition processes
- Both studies are consistent with a possible influence of language switching ability in language control.
- Is there a link between language switching and domain-general inhibition abilities ?

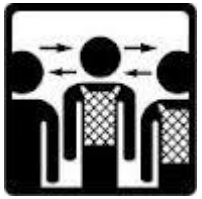
Aim of experiments 3 & 4

- Investigate switching aspects asides with inhibition conponants (current inhibition and overcoming of inhibition) in tasks involving language control as well as domain general control.

- Compare performances of several populations (bilinguals, simultaneous interpreters, monolinguals).
  - These populations are supposed to possess different skills in terms of inhibition efficiency.

Experiments 3a&b

- Examine the influence of the use of different inhibition processes above bilingual's performance in two task involving inhibitory control
- The inhibitory control required is modulated by the task: language control (language decision task) or cognitive control (bilingual Stroop task)
- Participants used in their daily lifes to use different inhibition processes : late bu high proficient bilinguals and simultaneous interpreters.



Simultaneous Interpreters (SI)

- Simultaneous interpreting is considered as a very complex linguistic task. extrêmement complexe (Christoffels et de Groot, 2005)

- Abilities to switch between languages and between tasks (comprehension/production) = Double switch :
  - Language switching
  - Task switching = shared conceptual attention (Mac Whinney, 2005);

- Advantage for interpreters in tasks involving Working memory (Köpke et Nespoulous, 2006 ; Köpke et Signorelli, 2012)

- Language control is of primordial importance for SI

Participants

24 late French-German Bilinguals, with a similar frequency of use of both languages

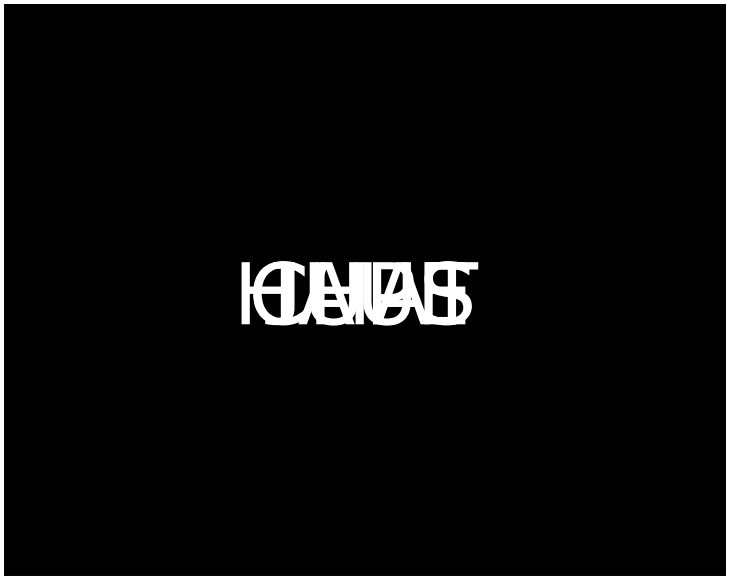
12 bilinguals = used to switch between languages

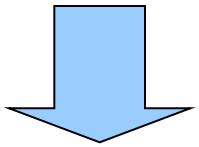
12 SI = used to switch between language and between tasks

	Age	AoA L2	Self rating (L2)	DAF (%)	Utilisation L2
Bilinguals	28,1 (5.7)	10,4 (0.8)	1,7 (0.5)	86,7 (7.2)	41,9 (16.3)
SI	35,1 (6.2)	10,3 (0.5)	1,2 (0.2)	95,8 (4.2)	45,4 (4.1)

Experiment 3a : language decision

Decide as quickly as possible to which language the target word belongs to





French

German

Material

320 non-cognate words (160 French, 160 German) matched in length (4-8 letters) and frequency (±80 OPM)

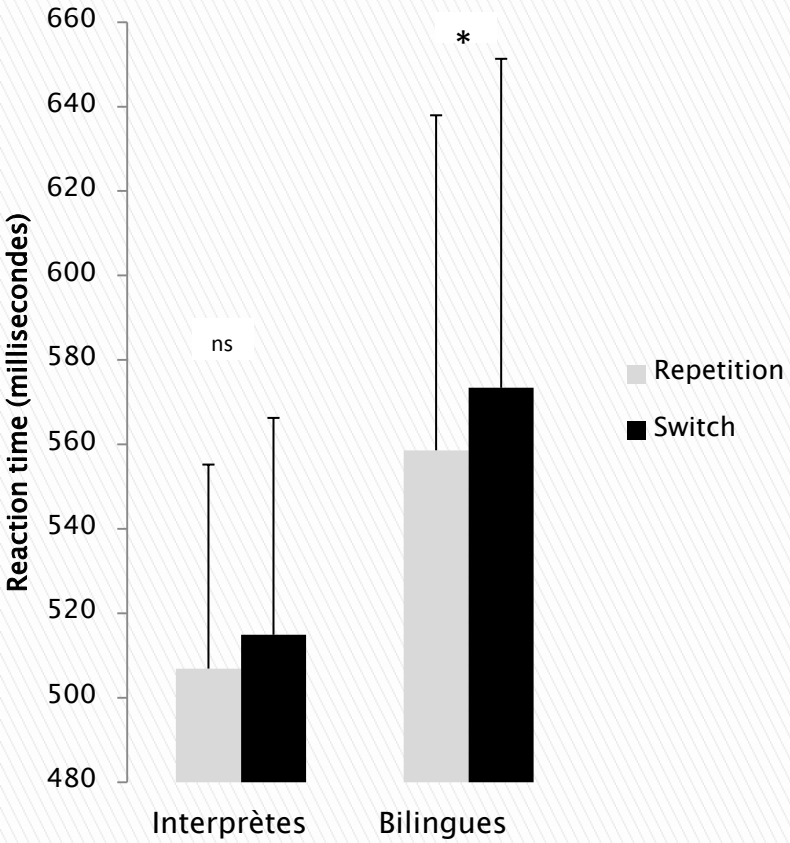
As much language repetition as language switching (Conan software)

LANGUAGE REPETITION				LANGUAGE SWITCH			
L1L1		L2L2		L2L1		L1L2	
n-1	n	n-1	n	n-1	N	n-1	N
VOITURE	MAISON	FINGER	GARTEN	BIRNE	CAMION	GLACE	STUHL

Hypotheses

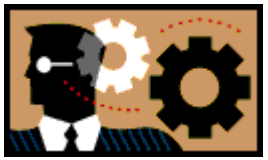
- Better cognitive control in SI = faster reaction times
- Slower processing of target words consecutive to language switching in comparison to language repetition
- Slowdown of processing associed to language switching in both groups, but in a larger extent in Late bilinguals.
  - Overcoming of inhibition more difficult than current inhibition (Mueller et al., 2009).

Results: language decision



- Interpreters faster than bilinguals
- Significant switch cost only for bilinguals
- Absence of asymmetry betweeen languages (switch direction L1→L2 = L2→L1 in both groups)

Discussion Experiment 3a



- Differences in terms of general language processing
- Different abilities in terms of inhibition
- Are these results due to a general mechanism of control, or to a specific mechanism of inhibition ?
- Better performances in terms of current inhibition or overcoming of inhibition ?

Experiment 3b: Bilingual Stroop task

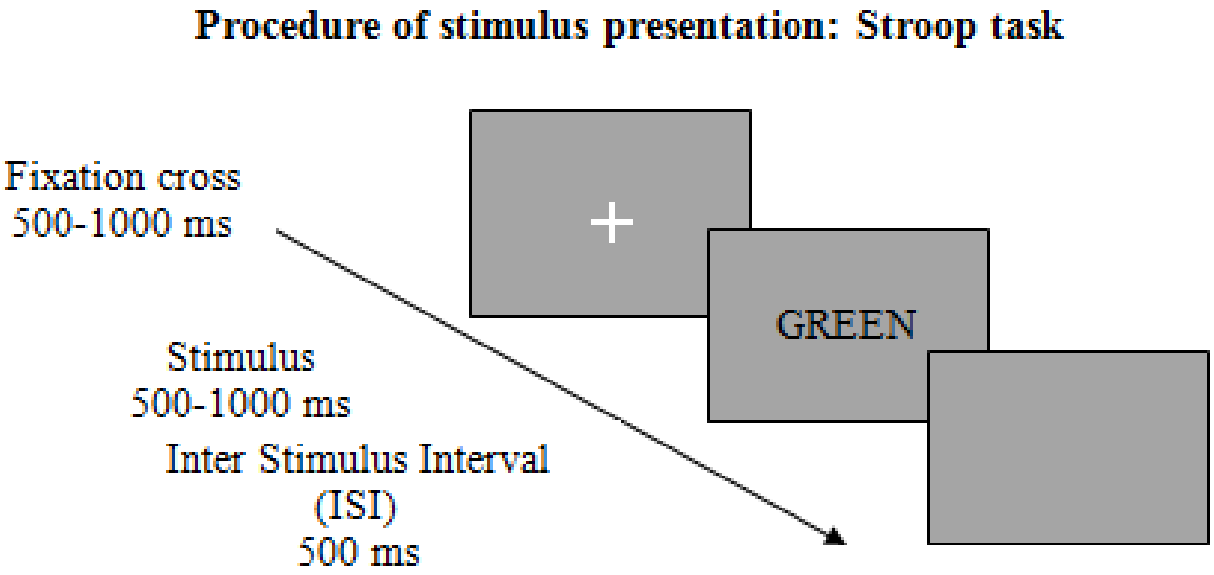
- Name the color of the word (control) and inhibit the reading of the word (automatic)

	Congruent	Incongruent	Neutral
L1	ROUGE	ROUGE	CHAT
L2	ROT	ROT	KATZE

- Stroop effect calculated by taking mean RT in incongruent condition from congruent condition.
- Size of Stroop effect obtained reflect the degree of inhibition involved in the task
- The smaller is the Stroop effect, the better is the control.

Procedure:

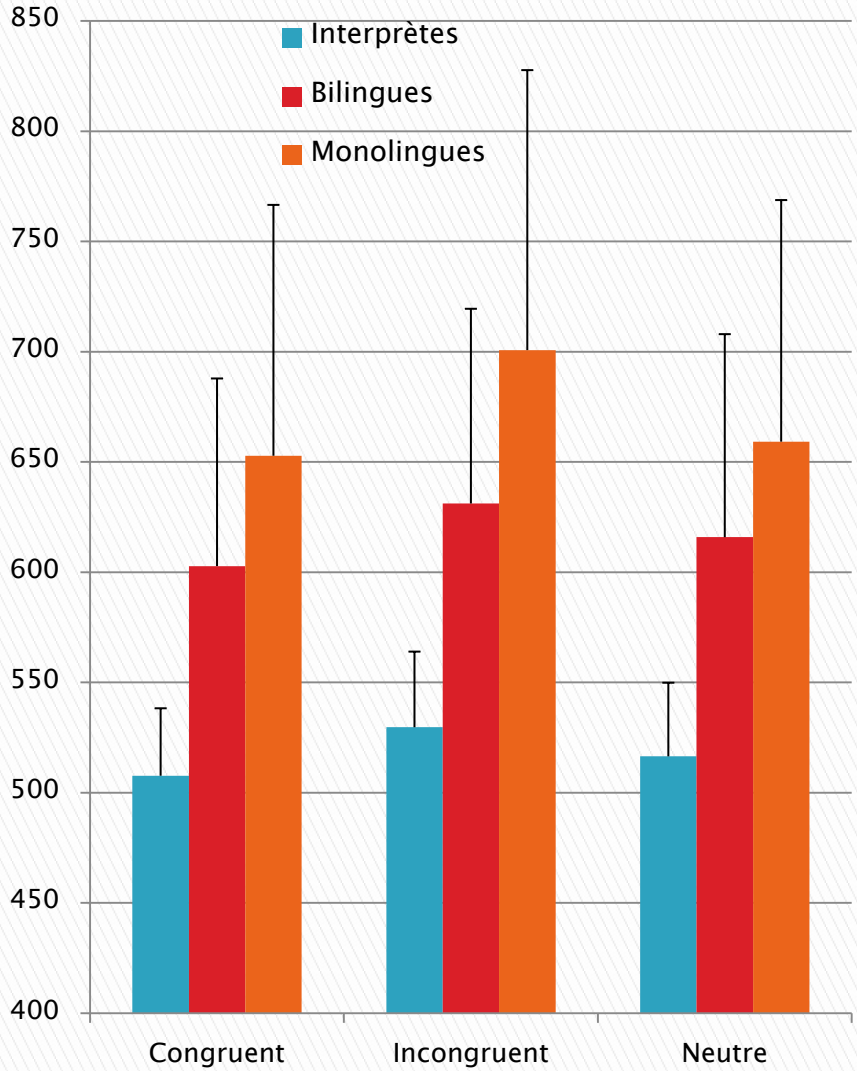
- 6 blocks of 72 trials



Hypotheses

- Better performances in SI = better performances in terms of current and overcoming of inhibition
- If lack of difference = better performances of SI in terms of overcoming of inhibition (Experiment 3a)
- Larger Stroop effect in L1 than in L2 (automaticity of L1, Heidlmayr, 2013).

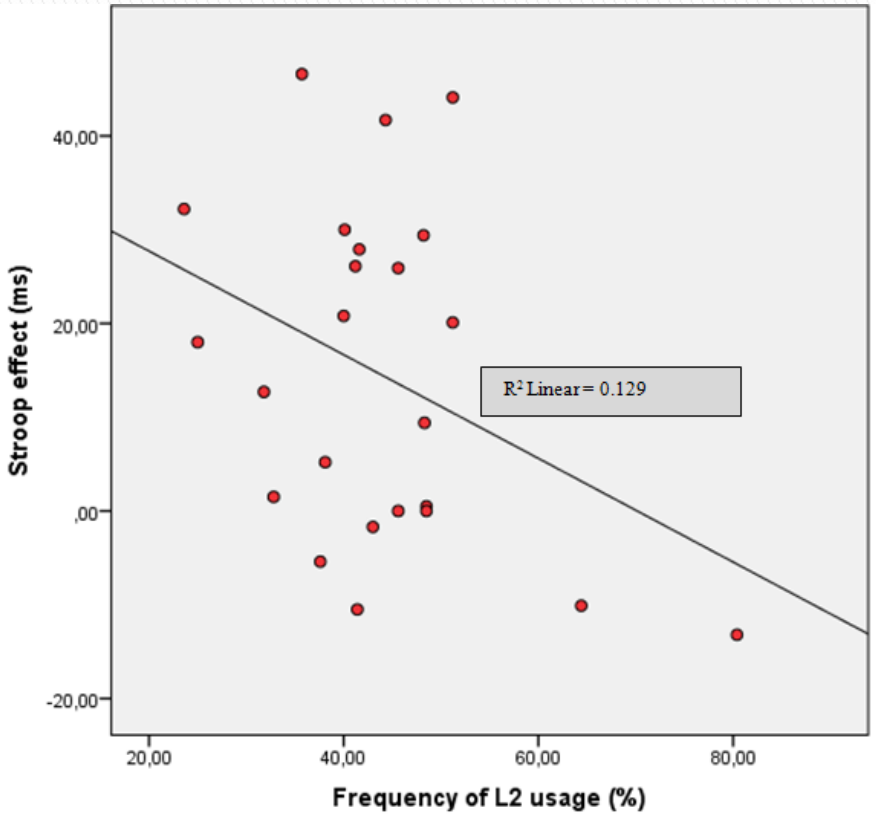
Results



- Faster RTs for SI
- Similar Stroop effect for both groups (18 ms vs. 22 ms)
- Similar performances in terms of current inhibition
- Larger Stroop effect for L1 (Heidlmayr et al., 2013) → L1 automaticity

Correlation and regression

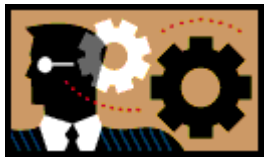
Predictors	R^2 increments (Coefficient β)	*t*	*p*
Constant	189.909	2.716	0.015
Age (years)	-0.109	-.563	0.581
Age of Acquisition (years)	-0.604	-3.561	0.002
Self-evaluation	0.345	1.408	0.177
DAF (%)	0.013	0.052	0.959
Frequency of L2 use [%]	-0.258	-2.515	0.148



AoA significantly predict Stroop effect

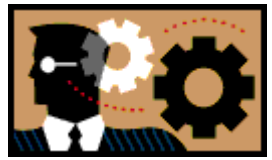
The more the use of L2 increase, the smaller is the Stroop effect

Discussion Experiment 3b



- Interpreters faster BUT
  - No differences in terms of Stroop effect (18 et 22 ms)
- Similar performances in terms of current inhibition
- Current inhibition associated with frequency of use of L2 rather than the ability to inhibit (Heidlmayr et al., 2012)
- Larger Stroop effect for L1 words in both groups (automaticity of L1 required stronger inhibition, cf. Aparicio & Lavaur 2013)

Discussion



- Better performances of SI in overcoming of inhibition →necessity to develop investigations of their cognitives skills (Köpke & Signorelli, 2012)
- Abilities could be link to frequent use of switching (between language and between tasks)
- If the inhibition/control processes involved in language switching are shared with domain-general control, what about inhibition of motor activities ?

Language & motricity

- Dorso-Lateral PreFrontal Cortex (DLPFC) involved in:
  - Cognitive tasks (code switching; Hernandez et al., 2001 ; Isel et al., 2010)
  - Motoric tasks (antisaccade ; Munoz & Everling, 2004).

➔ Asymetrical exchanges leaded by the linguistic context **(Aravena et al., 2012)**

Switch & Motricity

- Mueller et al., (2009): neurophysiological correlates associates with switch during prosaccade (look to a target, automatic) and antisaccades (control) in monolinguals
  - Prosaccades processed faster than antisaccades (pure blocks)
  - Switching effect for prosacccade only (Late Frontal Negativity)
  - Late Parietal Positivity highlighted for switch trials in comparison to repetition trials
- Bialystok et al., (2006): antisaccade taks in young and old bilinguals ➔ no effects of bilingualism but methodolgical issue to consider

Experiment 4

- Investigation of the influence of language switching ability on motor inhibition

- Top-down inhibition trained by a cognitive activity (language switching) could impact performances in a motor task necessiting an automatic motor answer.

  - Here inhibition of automatic answer towards the visual target to realize a controlled movement in the opposite direction (Hallett, 1978; Munoz & Everling, 2004; Collins et al., 2008).

Participants

- 12 bilinguals, 12 monolinguals

	Bilinguals		Monolinguals		T-test
	Mean	SD	Mean	SD	*p*
Age [years]	27.3	4.2	25	3.2	ns
Freq. of L2 use [%]	22.4	11.9	2	1.7	<.001
L2 PS [1: high – 5: low]	1.3	0.4	3.3	1.2	<.001
L2 PT %	84.8	11.1	---	---	---
AoA [Years]	10.0	1.9	11.2	0.7	ns
Immersion in L2 env. [years]	2.0	1.3	---	---	---
Age of immersion [years]	17.8	1.3	---	---	---
Music practice [hr/week]	0.3	0,6	0.3	0.6	ns
Sport practice [hr/week]	2.1	2	0.6	1.1	ns
Vid/comp games [hr/week]	0.1	0,1	2.5	5.7	<.05

Material & procedure

Prosaccade (automatic)

Antisaccade (inhibition/control)

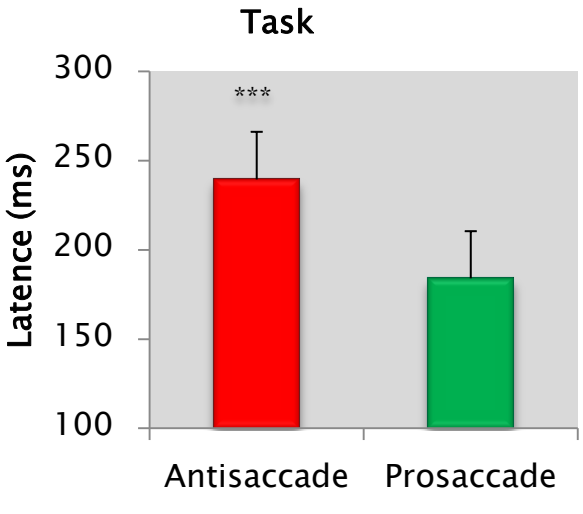
Pro	Mixed	Post
PS = 3 blocks	PS/AS = 6 blocks	PS = 3 blocks
AS = 3 blocks		AS = 3 blocks

21 blocks + 3 blocks of training

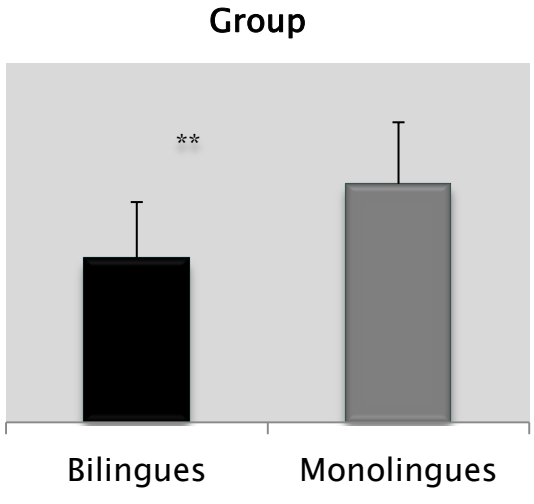
Hypotheses

- Effect of task: prosaccade < antisaccade (Mueller & al., 2009)
- Group effect: faster answers for bilinguals vs. monolinguals
- Training effect: blocks presented after the mixed session should be processed faster than those presented before this session.
- Switching effect: larger in monolinguals in comparison with monolinguals

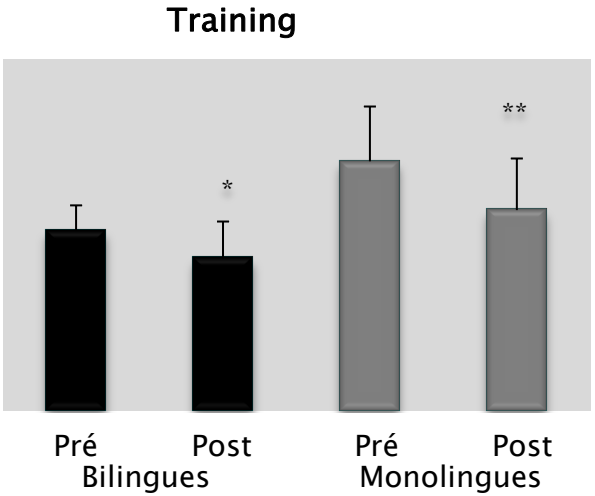
Results



Prosaccades are processed faster

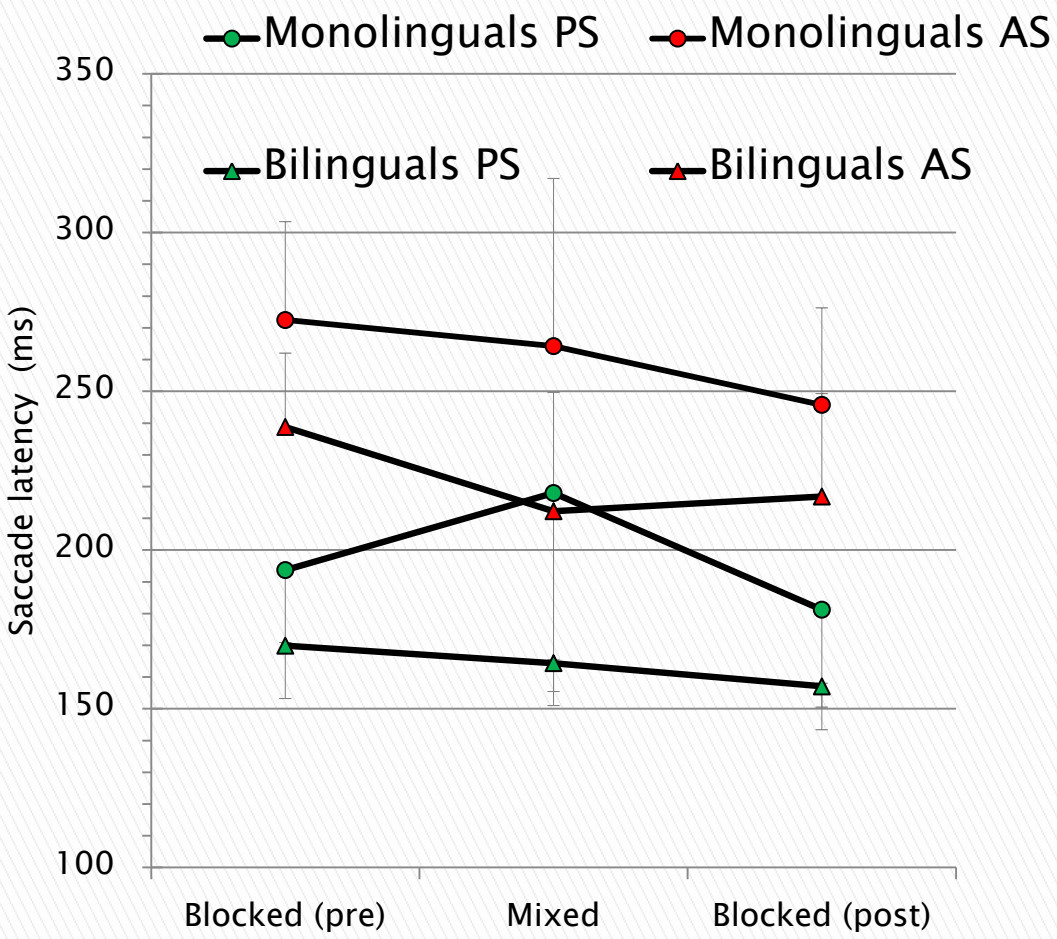


Bilingual advantage (even for prosaccades !)



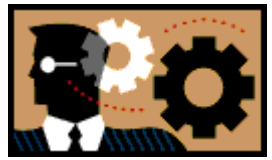
Training effect in both groups, but larger for monolinguals.

Results



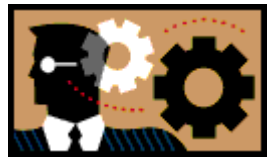
- **Switching effect**
- Verified in monolinguals only
- And only for prosaccades trials (consistent with Mueller et al., 2009)
- Absence of effects in bilinguals suggests better aptitudes in terms of cognitive control associated with the mastering of several languages

Discussion Experiment 4



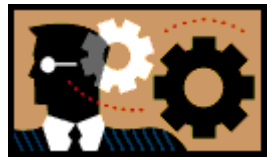
- Task effect replicated (Munoz & Everling, 2004)
- Bilingual advantage in a non-linguistic task
- Results in contrast to Bialystok et al. (2006) = methodological constraints ? (gap 1000 ms)
- These results are consistent with the hypothese of shared inhibition processes for cognitive ans motor structures.

Discussion experiment 4



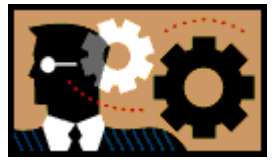
- Training is more efficient for monolinguals
- Switch effect for monolinguals only and for prosaccades trials (Mueller et al. 2009).
- Therefore, it is not the active inhibition that could account for bilingual advantage, but rather overcoming of inhibition.

General discussion



- Language switching seems to be an interesting tool to investigate language control processes in bilinguals.
- Could account (partially) for performance in terms of executive functioning and inhibition.
- Inhibition componants are of major interest in the study of language control.

General discussion



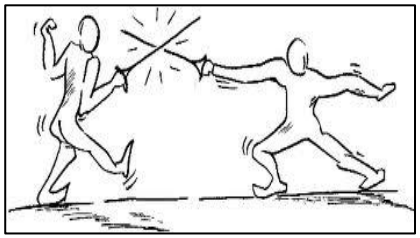
- Performances in language switching modulated by AoA as well as proficiency
- Necessity to develop studies and questionnaire to increase our understanding of language acquisition as well as strategies of learning, that could impact language control performance
- Questionnaire taking into account linguistic history as well as frequency of daily language switching

Perspectives

COGNITION

ACTION

BILINGUISME



EXPERTISE SPORTIVE

Cognitif + / Action –

Cognitif – / Action +

- Test Stroop
- Test Simon
- Tour d'Hanoi
- Go-no Go
- Stop signal
- Antisaccade

Collaborateurs : Karine Doré-Mazars, Karin Heidlmayr, Frédéric Isel, Jean-Marc Lavauret Christelle Lemoine