Inhibitory control in L2 phonological processing

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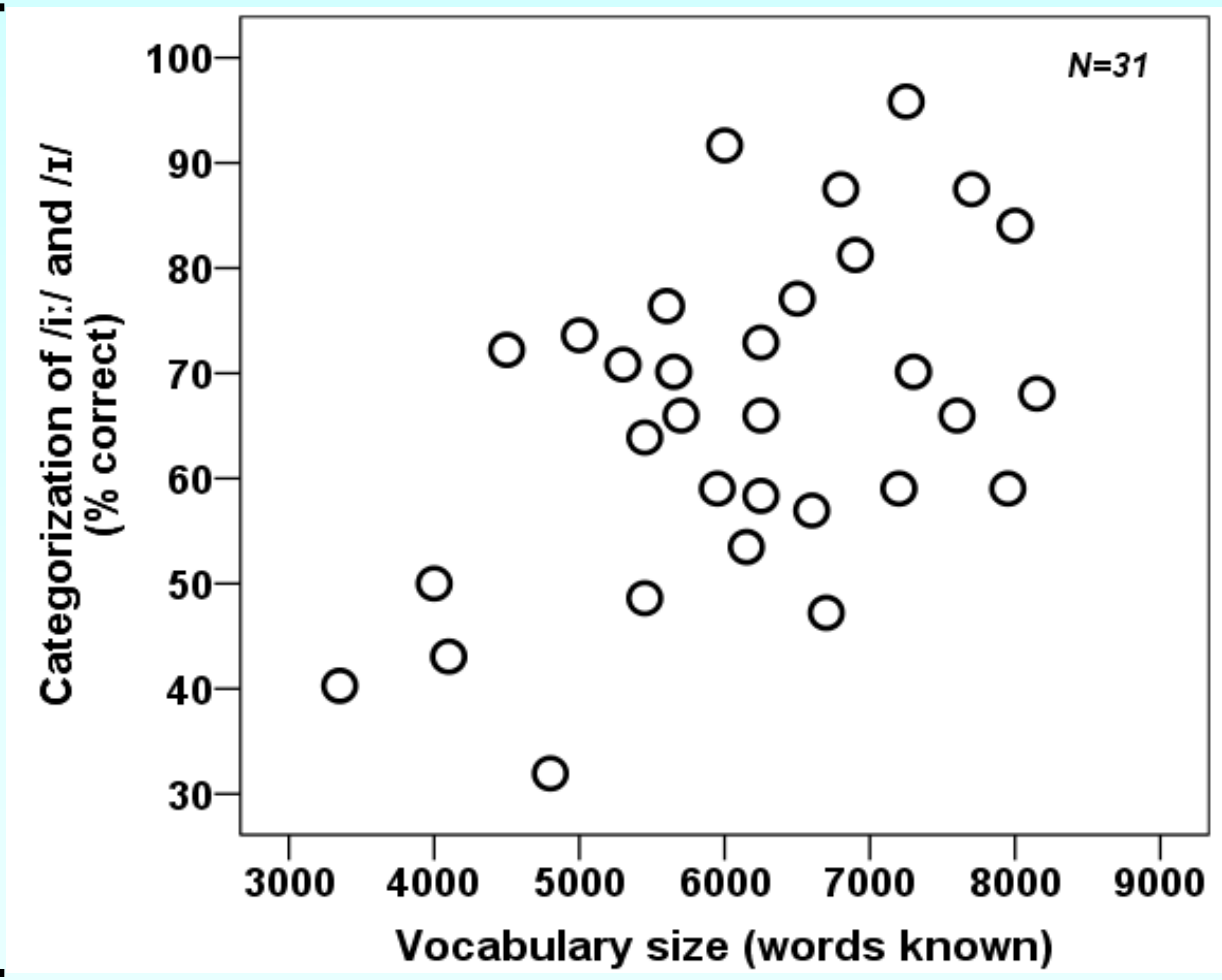
Language Control in Second Language Learners. Université de Toulouse II – Le Mirail, June 18 2014

What motivates this research?

(a) Many L2 learners struggle with pronunciation.

(b) Age- and Experience- / Input-related factors do not fully explain inter-learner variation in L2 phonological competence.

Perception of L2 vowels



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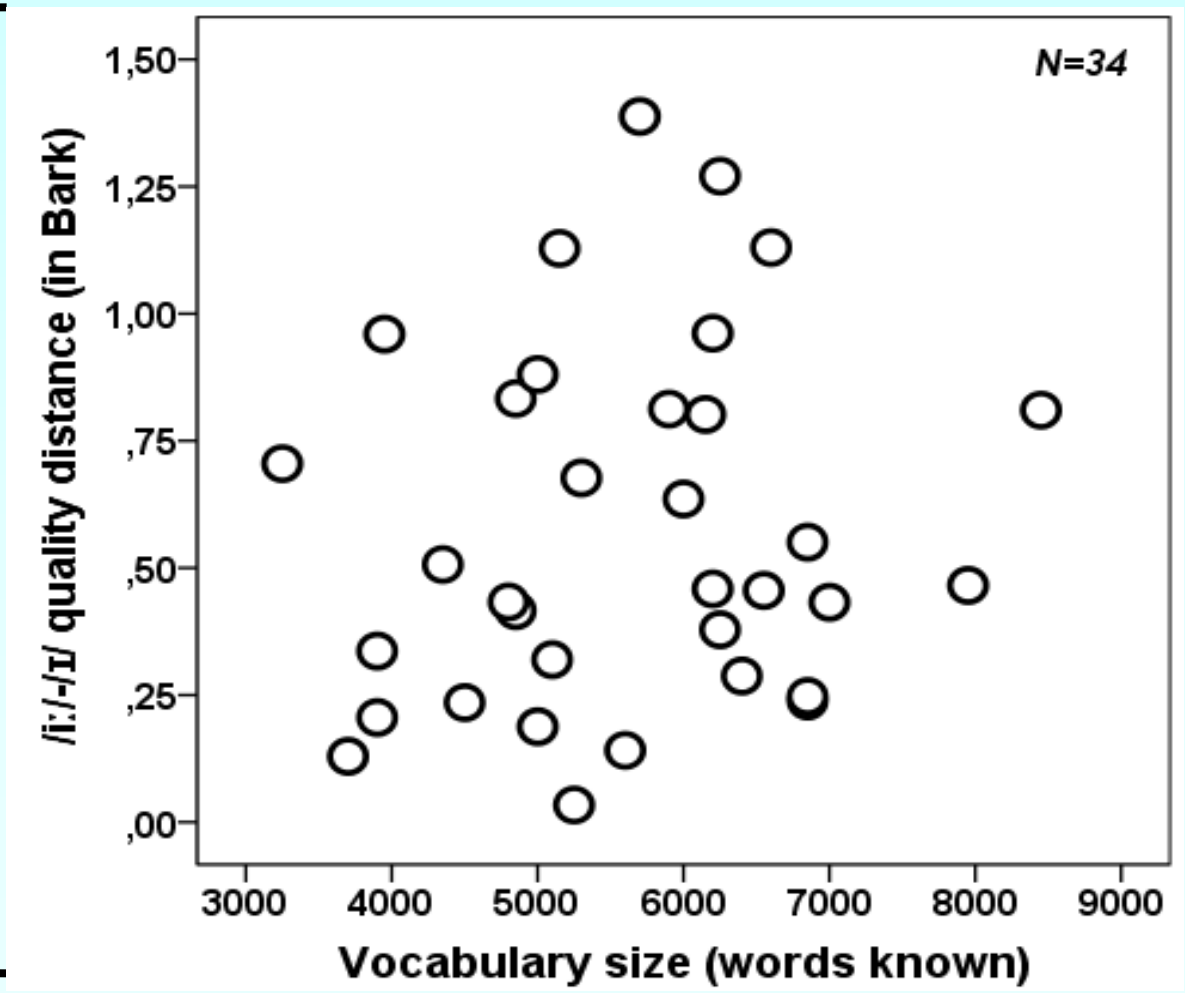
Production of L2 vowels



Inhibitory control: definition

Inhibitory control:

A person's ability to bring to the background stimuli (visual, auditory) or stimuli features (colour, shape) that are irrelevant to the mental process at hand.

(Miyake et al., 2000)

2 main types of inhibition (or inhibitory control):

(a) Deliberate, intended controlled suppression of a prepotent response: one's ability to deliberately inhibit dominant, automatic, or prepotent responses when necessary (Stroop task).

(b) the suppression of activation in spreading activation models

- **(b1) decrease in activation (negative activation)**
- **(b2) reactive inhibition = negative priming (unintended inhibition resulting from processing)**

Inhibitory control and language

Inhibitory control in language:

(a) Inhibition of the language not in use

(bilingual language control: L1/L2)

(b) Suppression of activation of phonological / lexical representations.

(lexical selection in word retrieval processes)

Is inhibitory control a cognitive skill modulating L1 interference and attrition?

(Costa & Santesteban, 2004; Costa, Santesteban & Ivanova, 2006; Lev-Ari & Peperkamp, 2013; Miyake et al., 2000)

Tasks used to measure Inhibitory Control

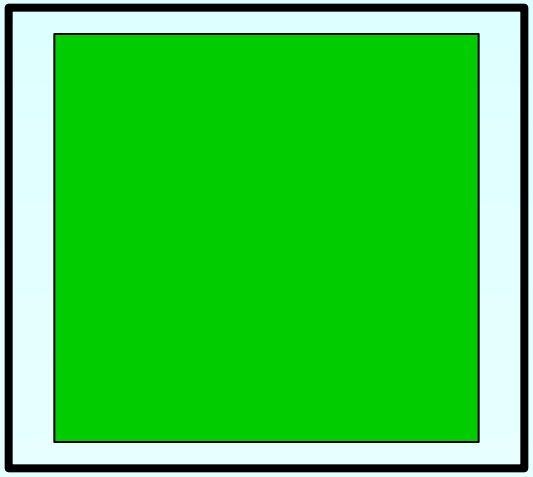
- Linguistic vs. Non-linguistic
- Intentional vs. non-intentional inhibitory control

- Simon
- Flankers
- Stroop
- Language switching
- Retrieval-induced inhibition

Simon

Press the left key for the GREEN square, and the right key for the RED square (ignore the position of the square)

Congruent



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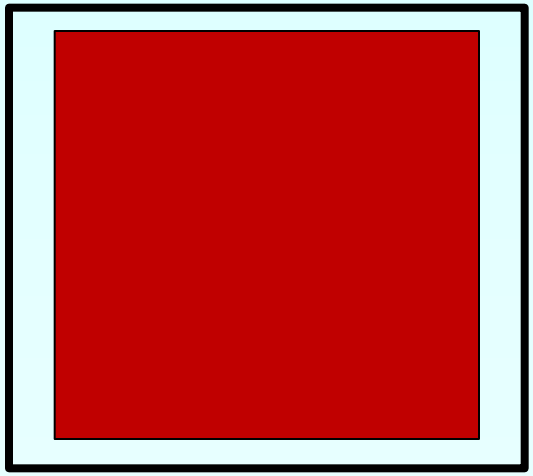

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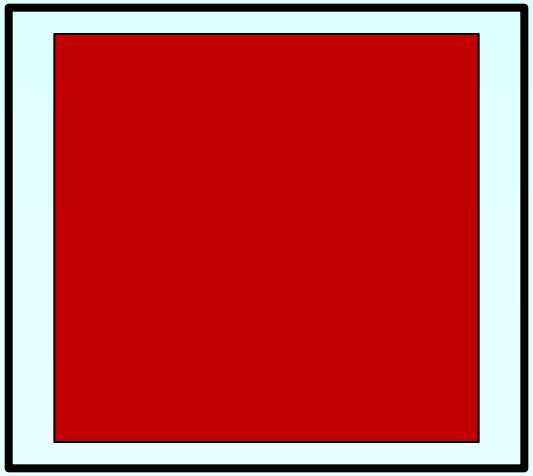

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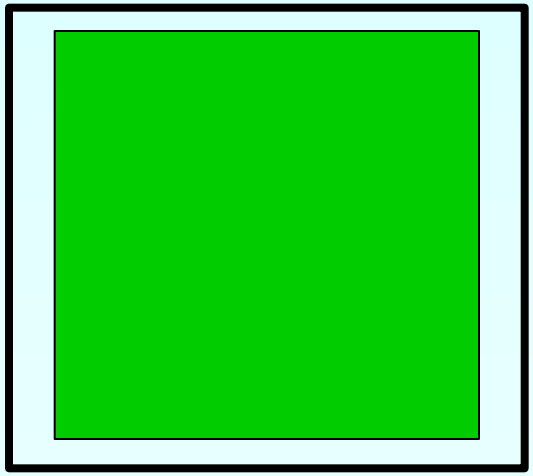
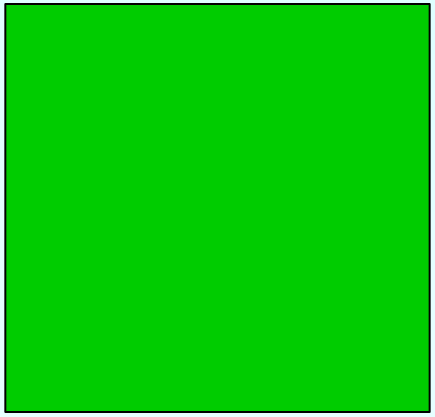


Simon

Ready?

Simon



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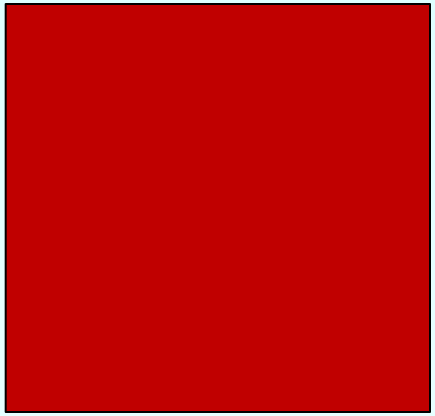

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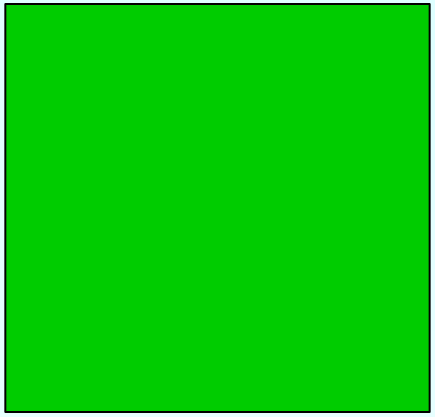

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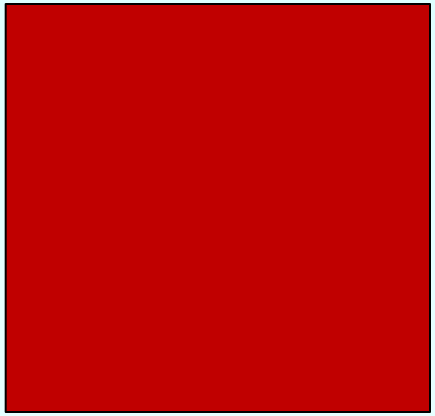

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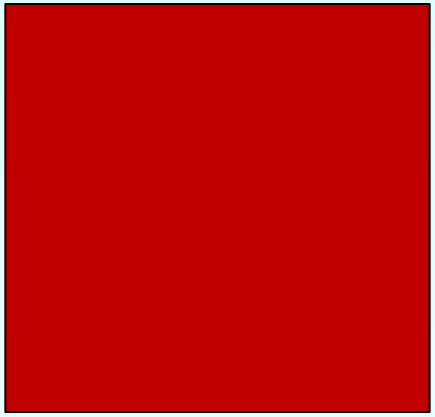

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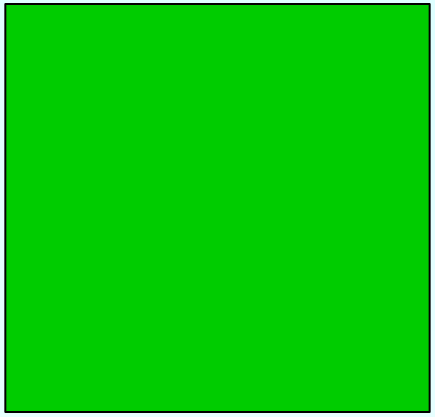

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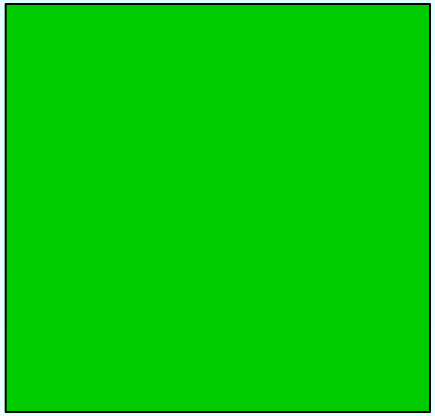

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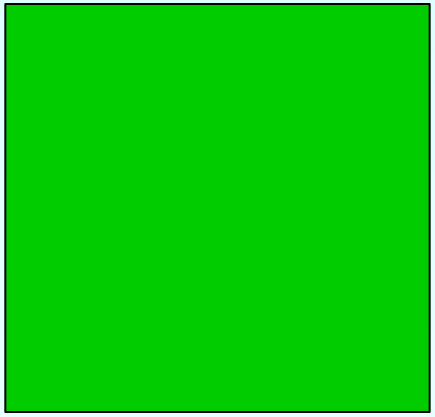

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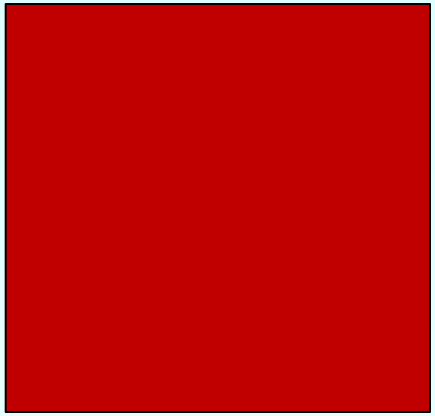

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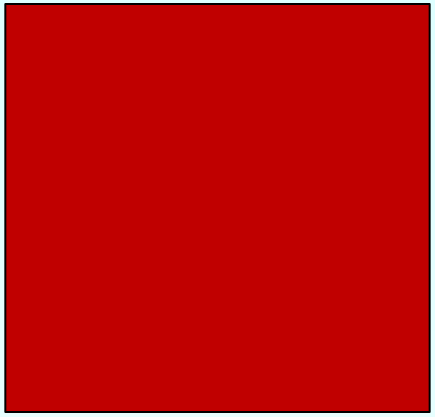

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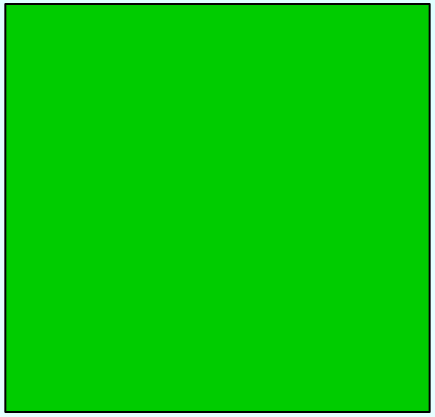

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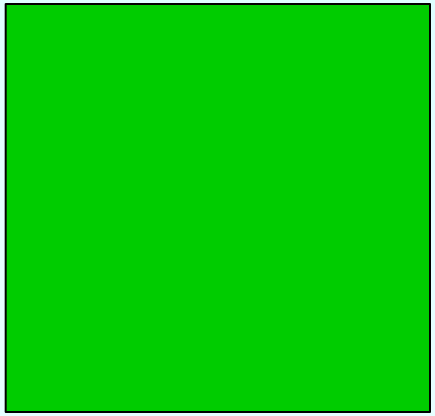

Flankers

Blumenfeld, H. K., & Marian, V. (2013). Parallel language activation and cognitive control during spoken word recognition in bilinguals. *Journal of Cognitive Psychology, 25*(5), 547-567.

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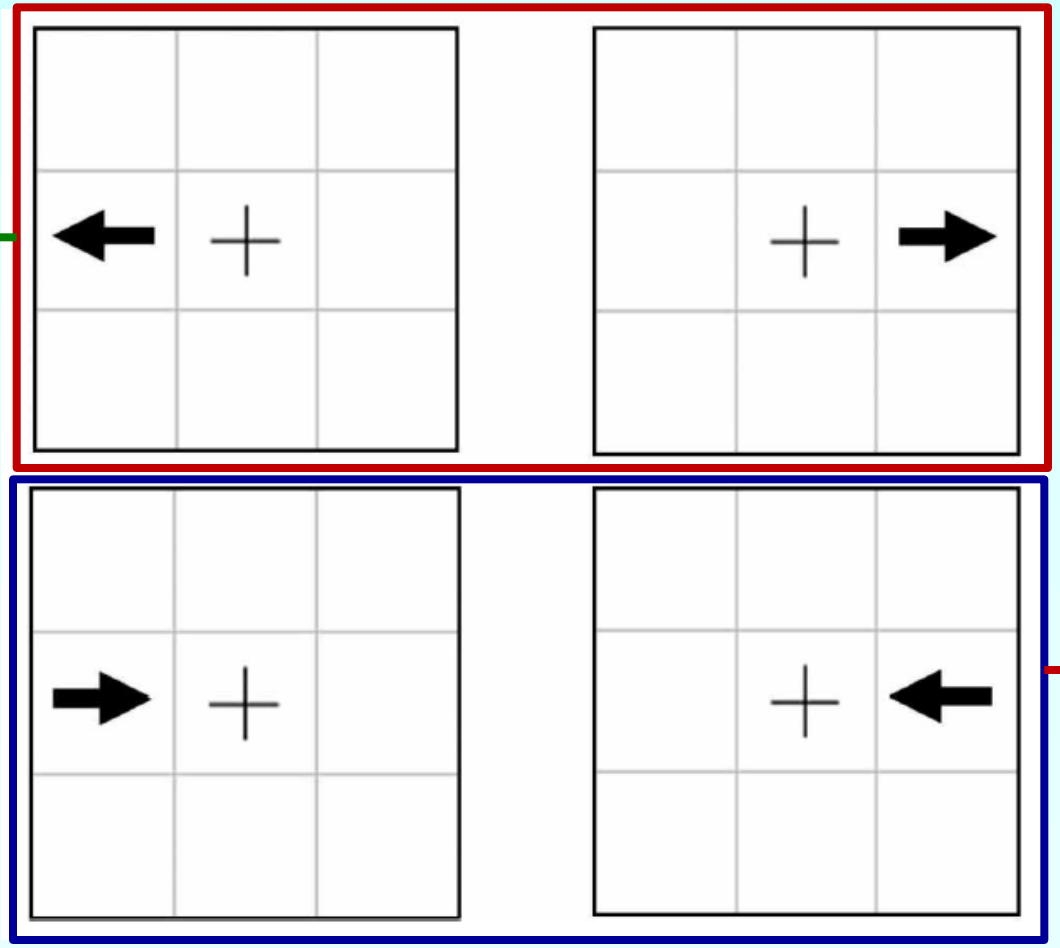

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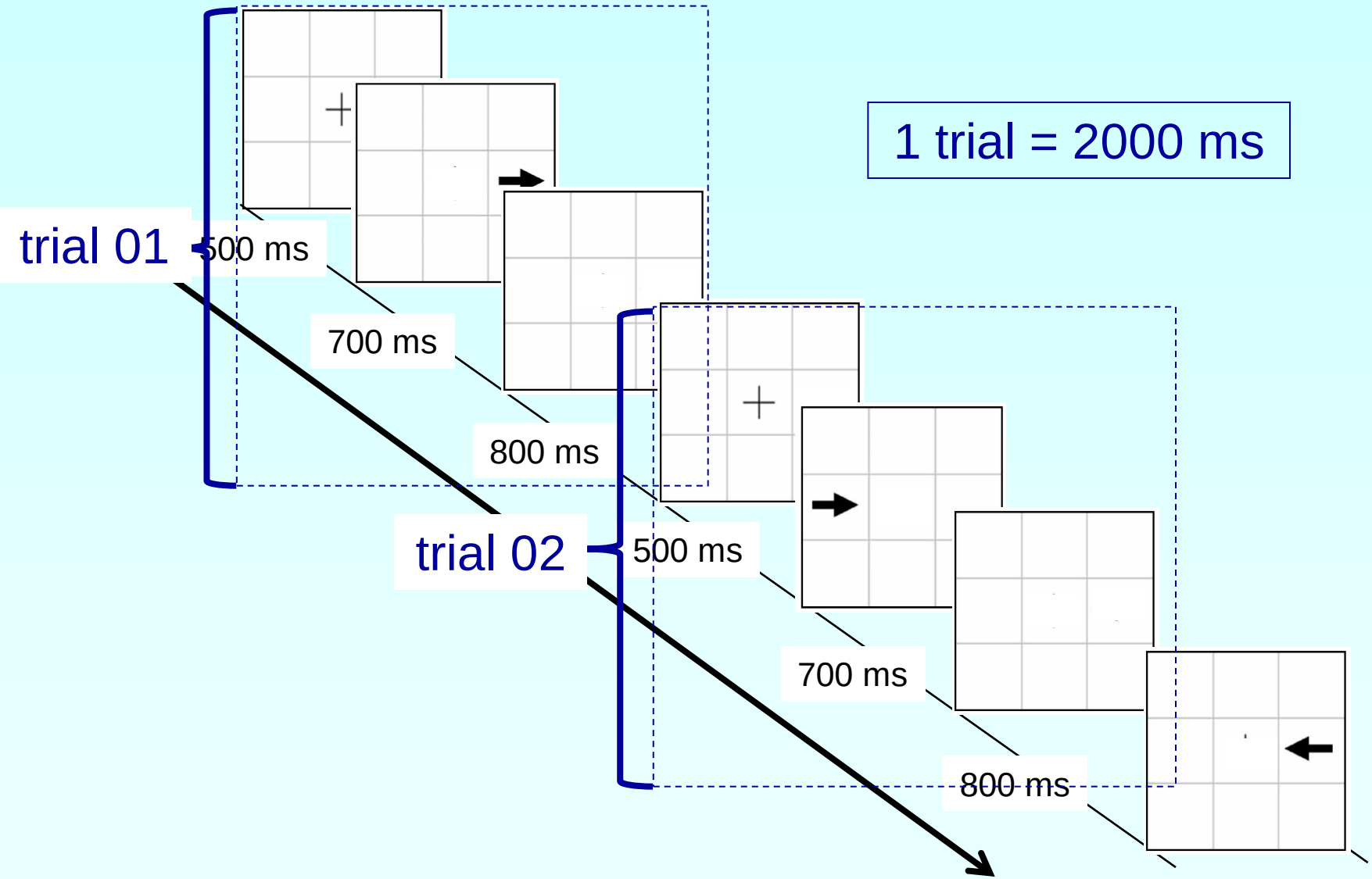

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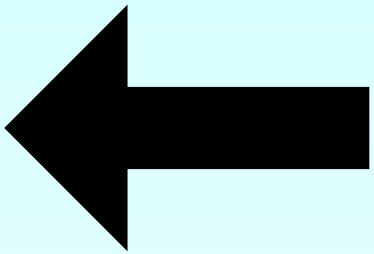

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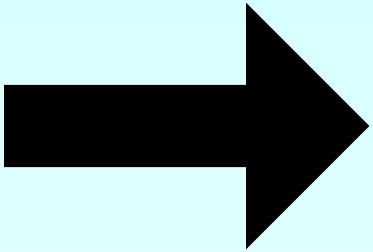

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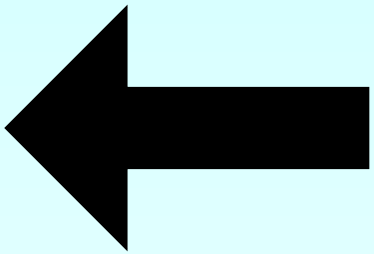

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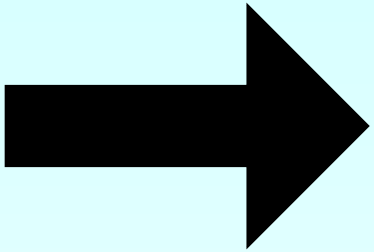

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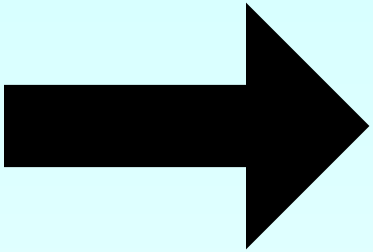

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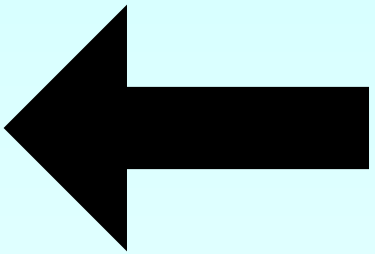

Stroop

Name the ink colour (ignore the word).

Stroop

Name the ink colour (ignore the word).

green

Stroop

Name the ink colour (ignore the word).

blue

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Name the ink colour (ignore the word).

red

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blue

Inhibitory control & L2 phonology

Few studies relating Inhibition to L2 phonological development

(Lev-Ari & Peperkamp, 2013; Darcy, Mora & Daidone, 2014)

- → **Stronger inhibitory skill might result in better inhibition of the language not in use, and in more efficient phonological processing when switching between speech dimensions or languages.**

- → **Greater inhibitory capacity may lead to more successful suppression of L1 interference in L2 phonological processing.**
  → **more accurate L2 speech perception/production.**

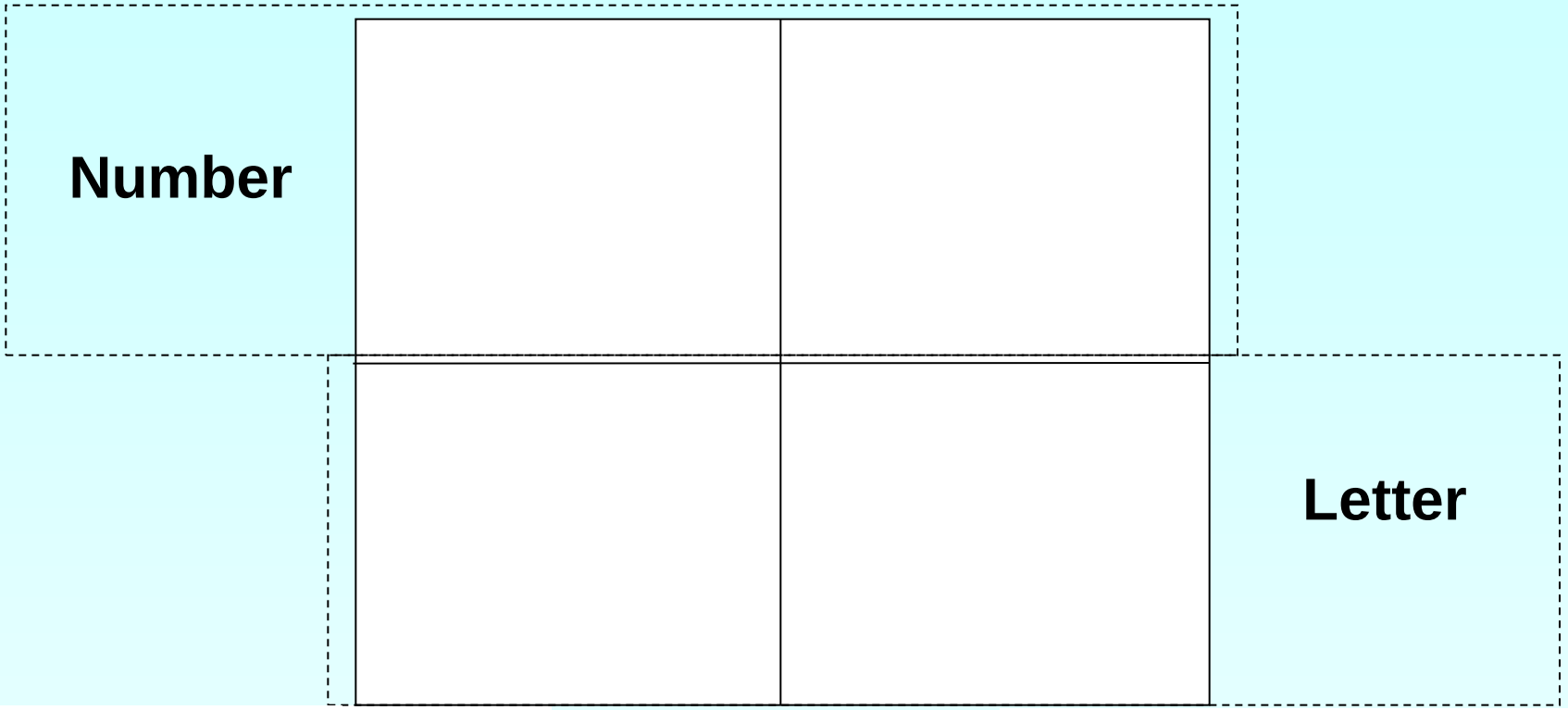
Inhibitory control & L2 phonology

In SLA

→ **Switching between languages ≠ bilingualism**
- large differences in language dominance

→ **Switching between speech dimensions ≠ L1 or L1s**
- is not effortless / automatic
- Phonetic cue weighting may be different in L1 and L2

Example 1: task switching paradigm



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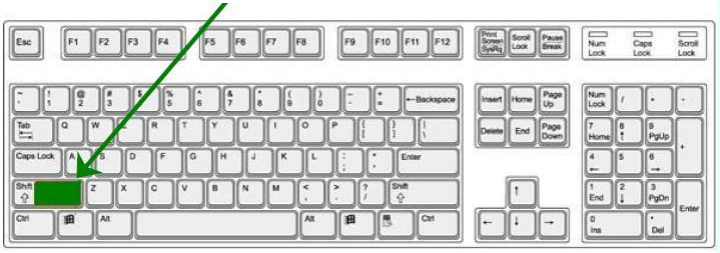
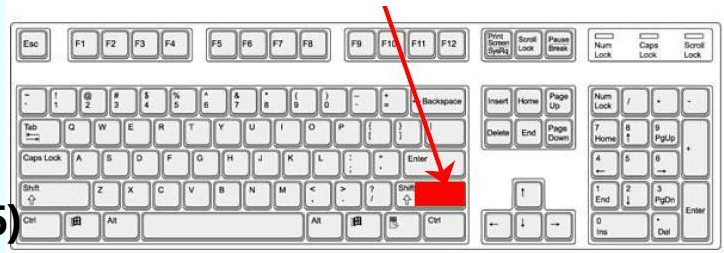
even **Right key** consonant





Rogers & Monsell (1995)

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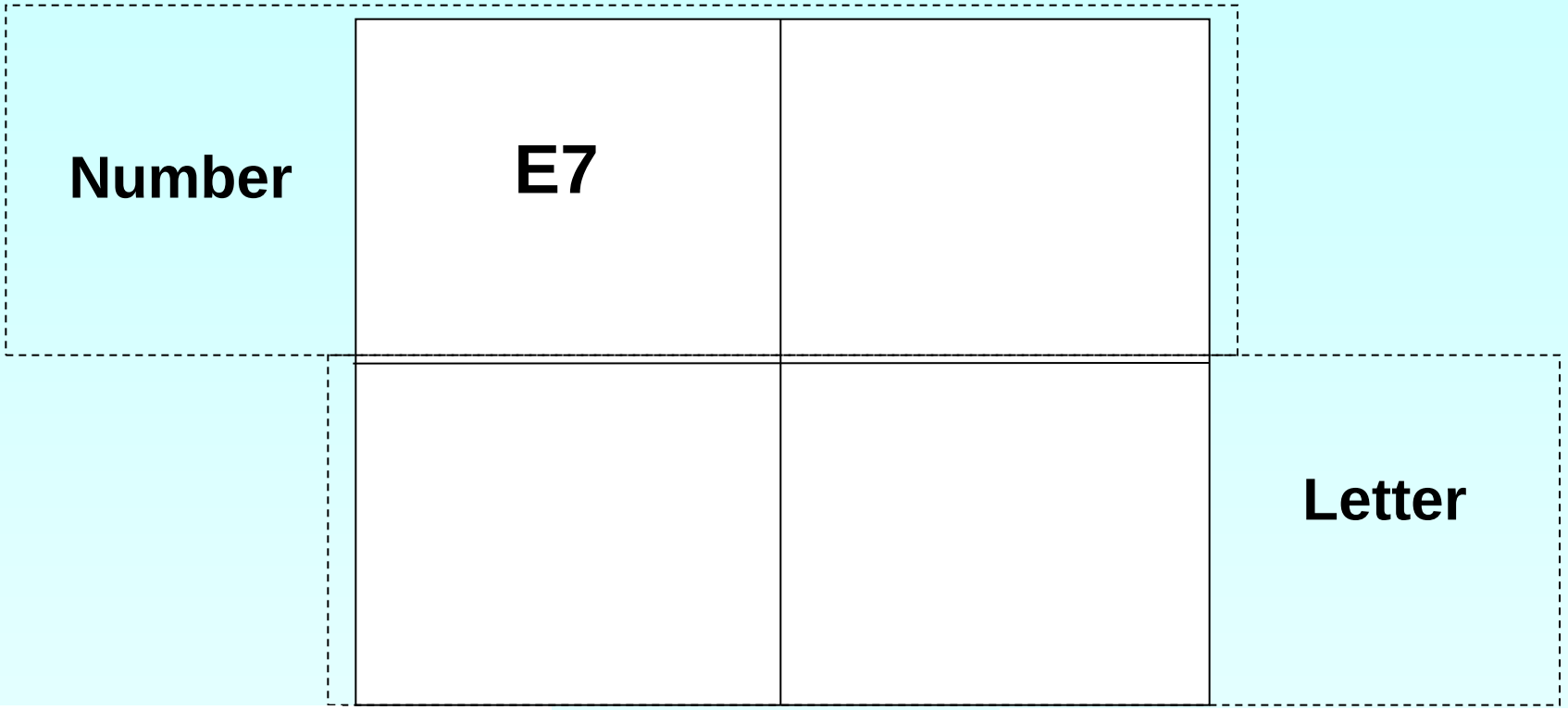

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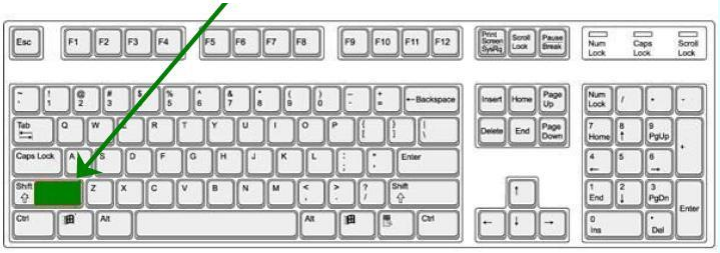

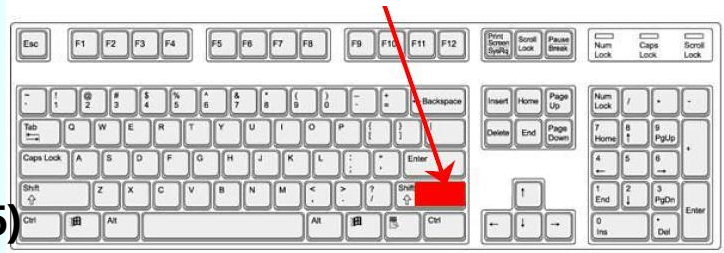

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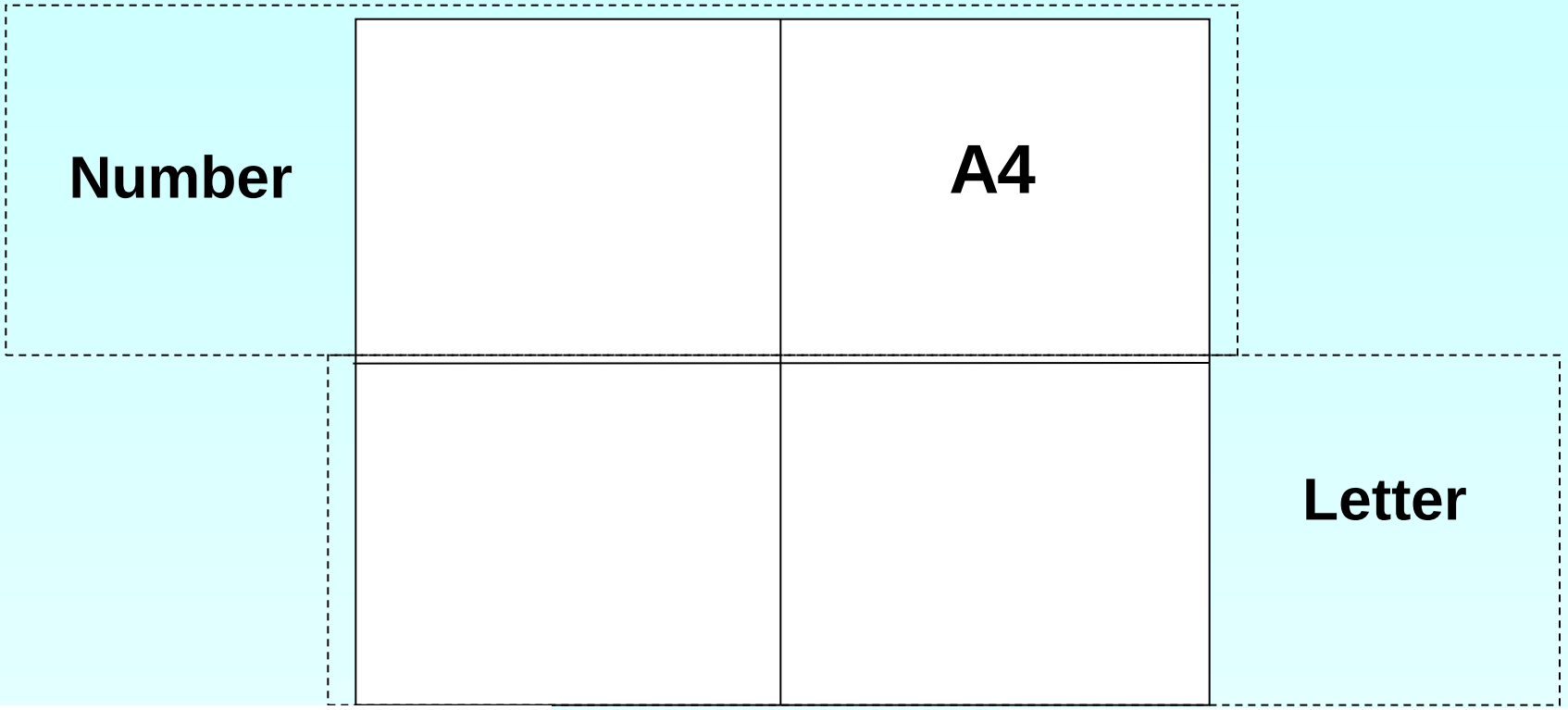

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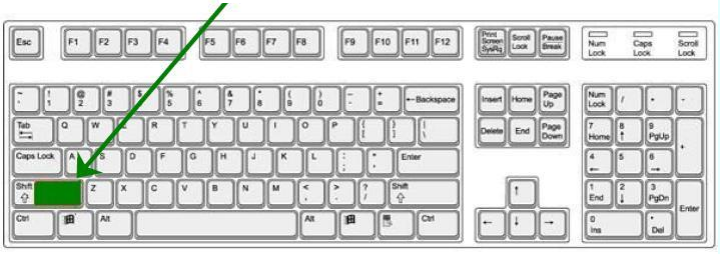

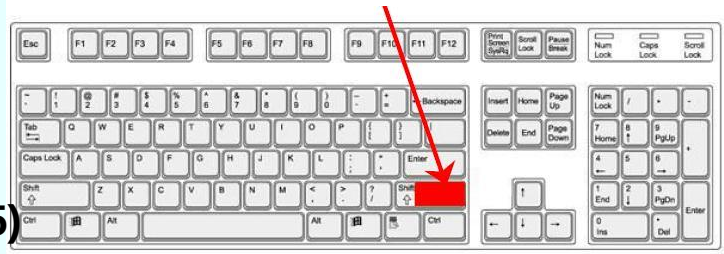

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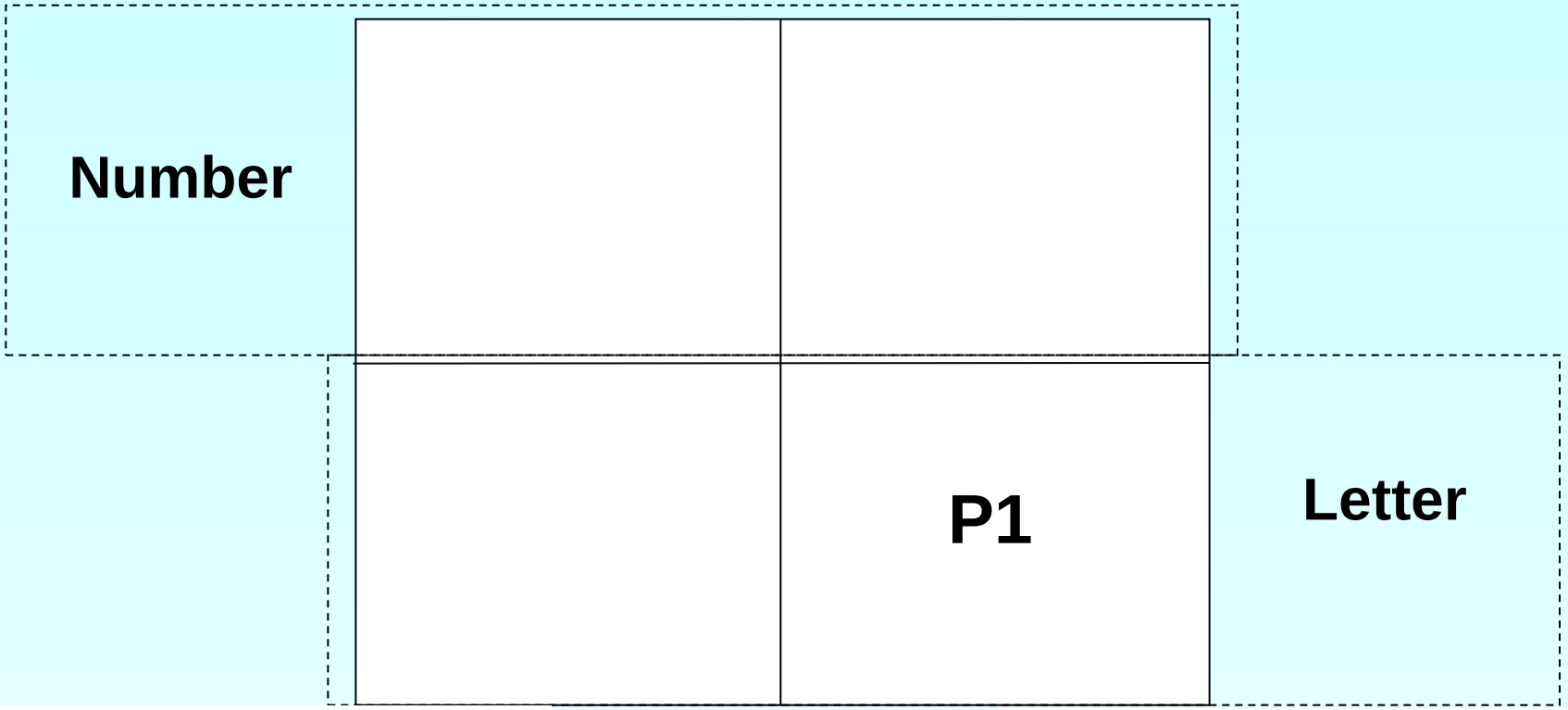

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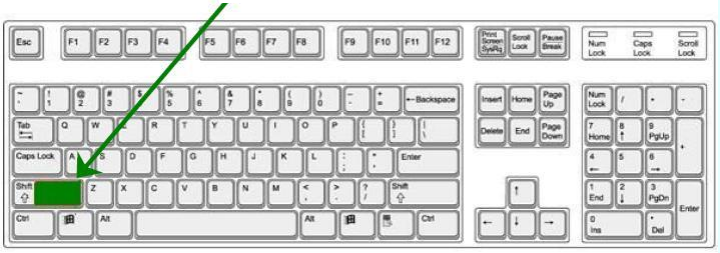

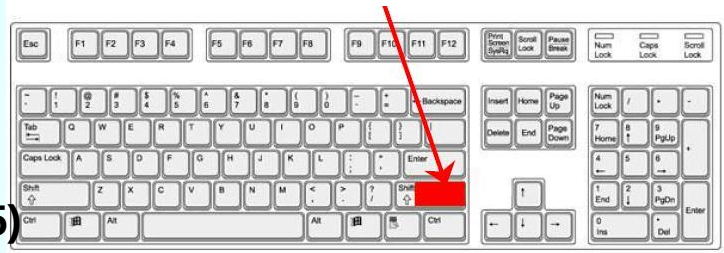

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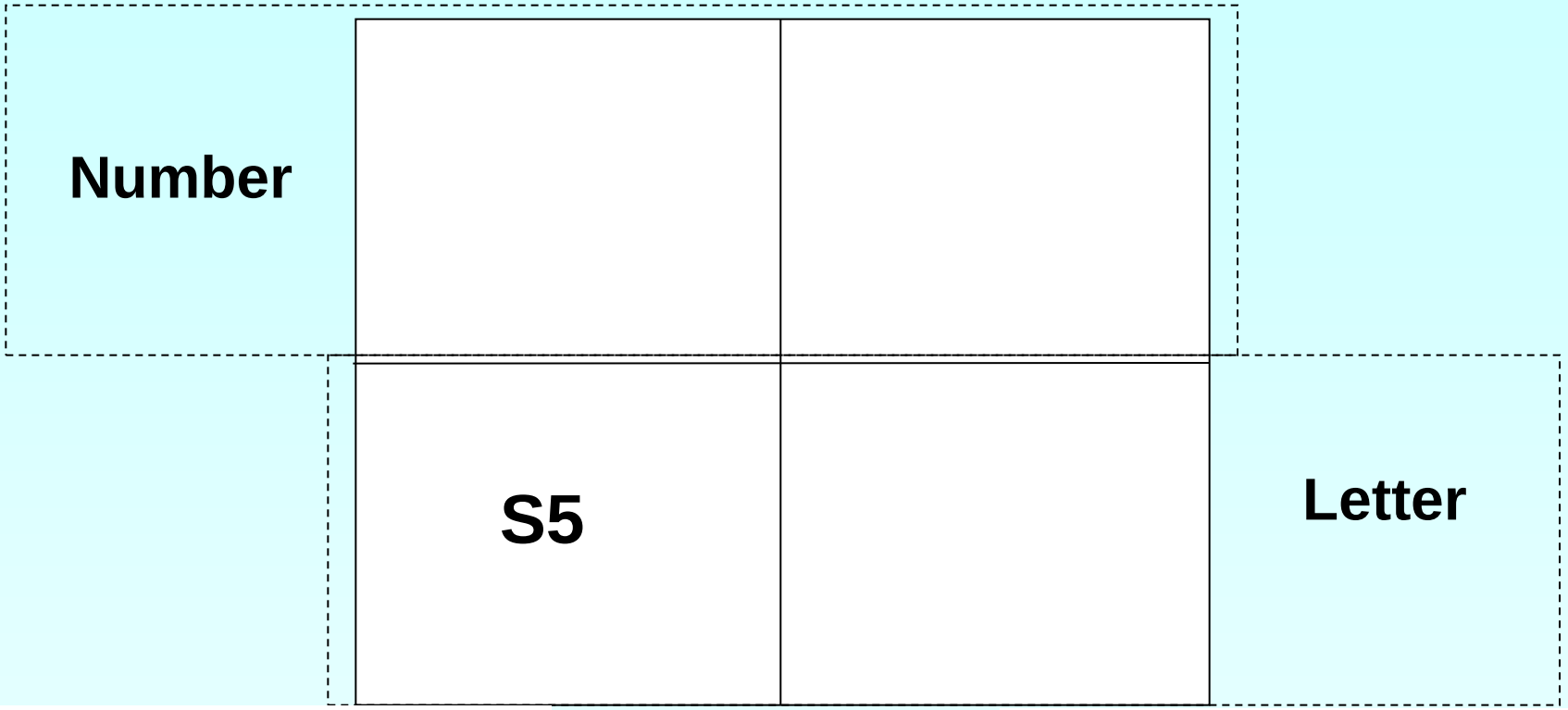

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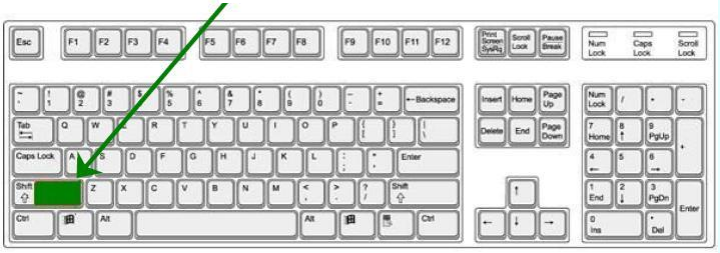

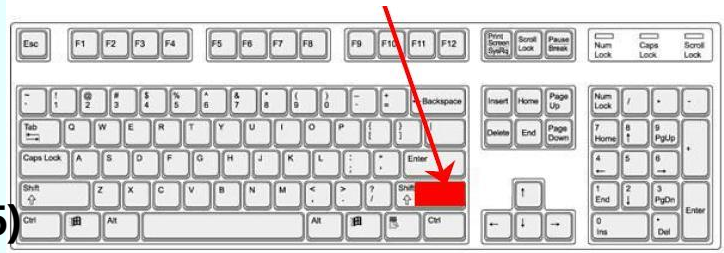

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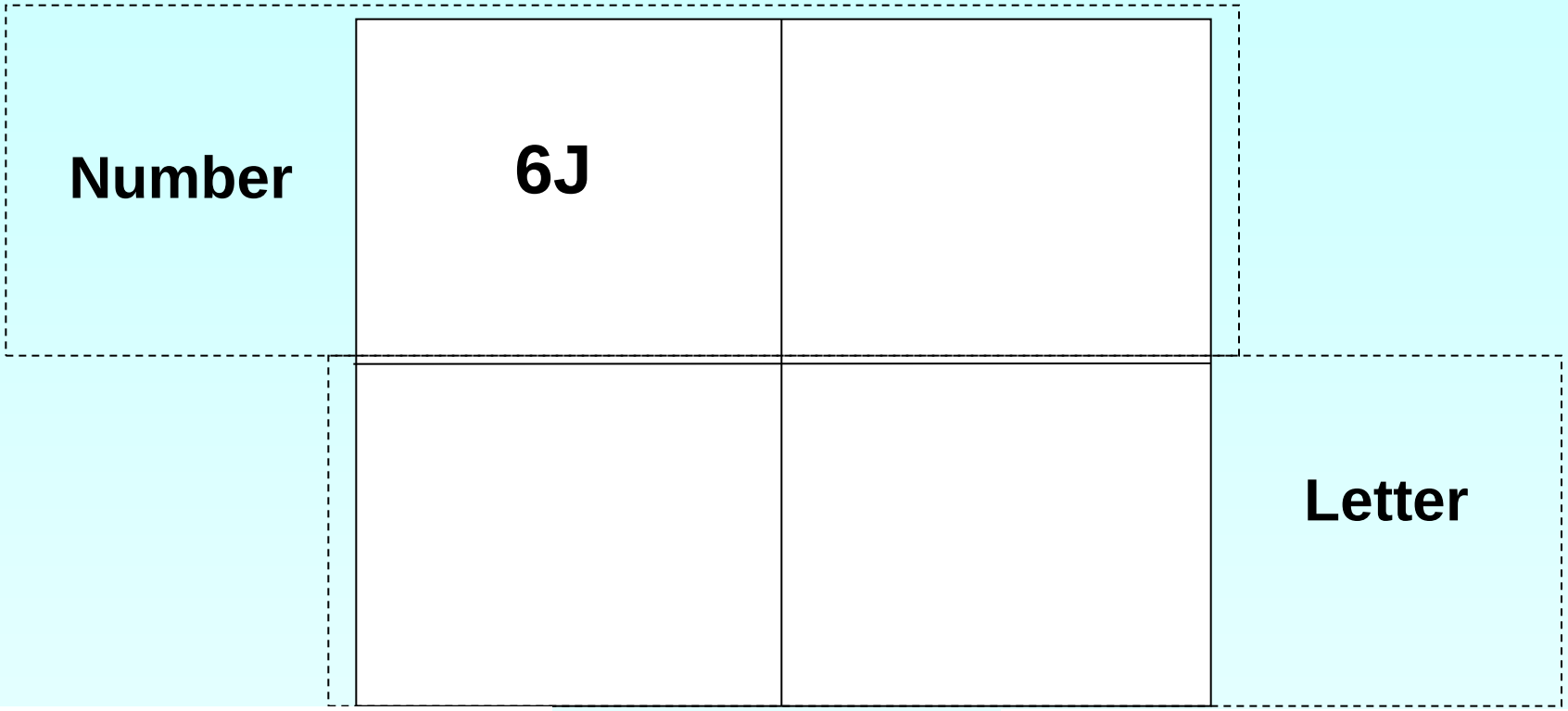

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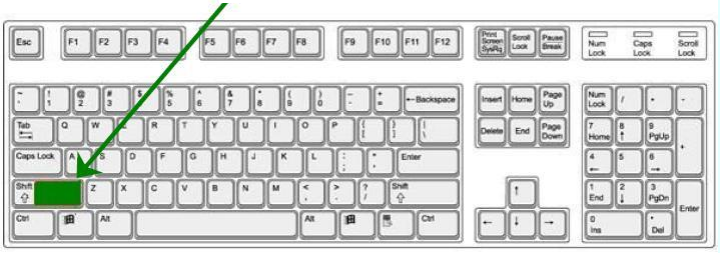

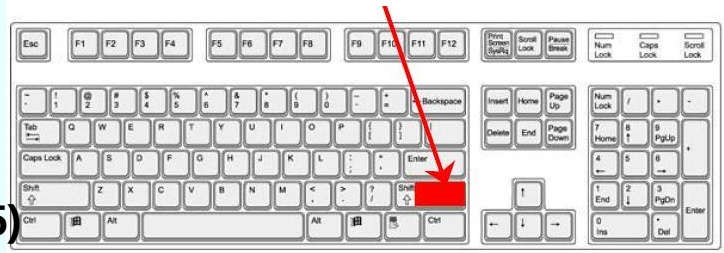

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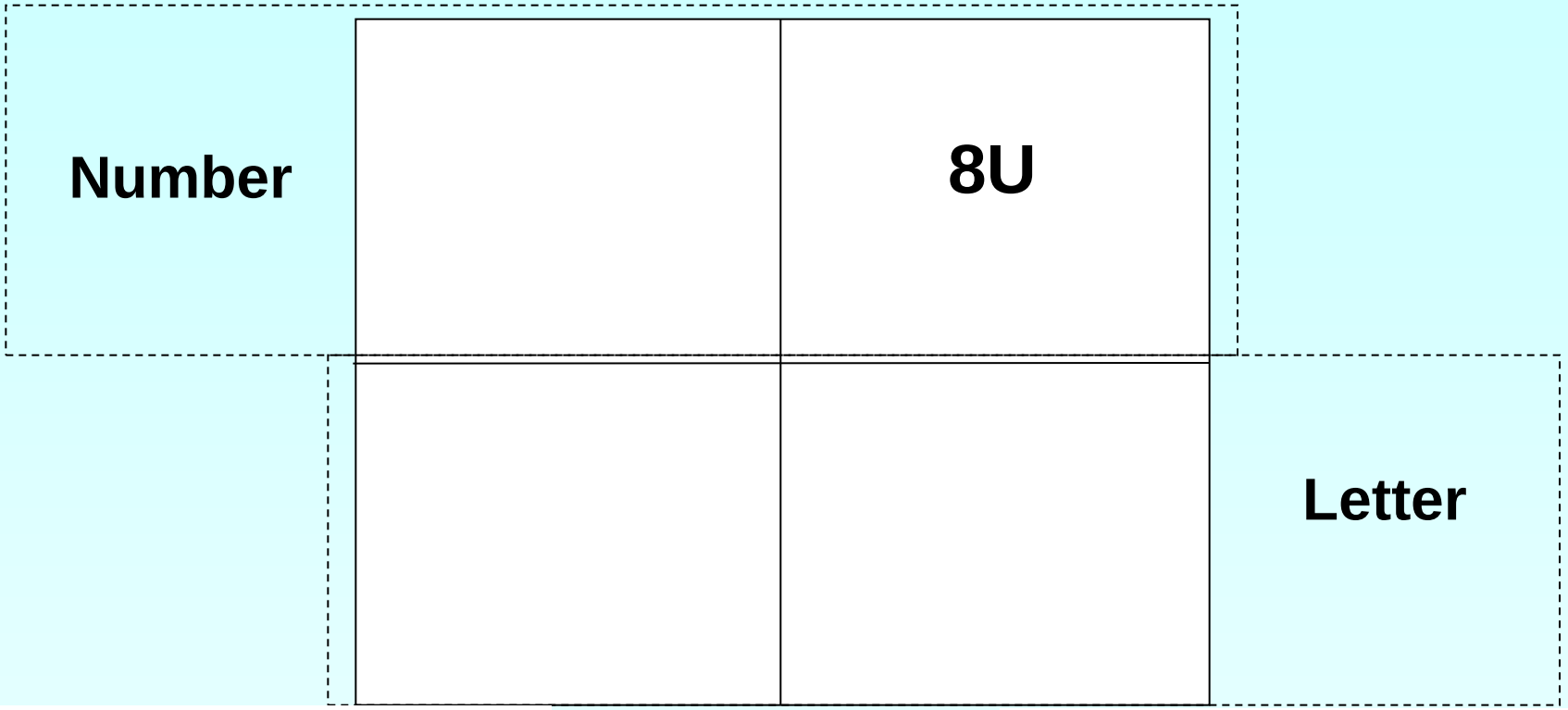

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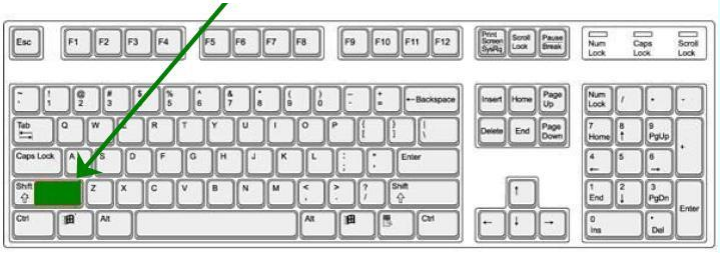

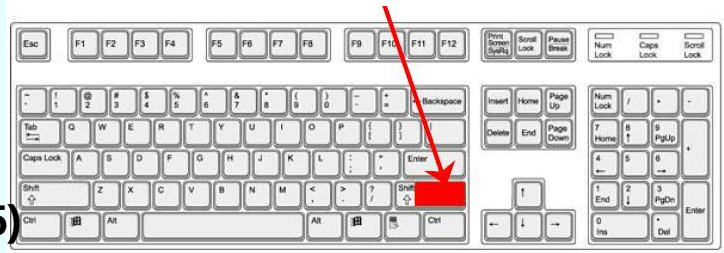

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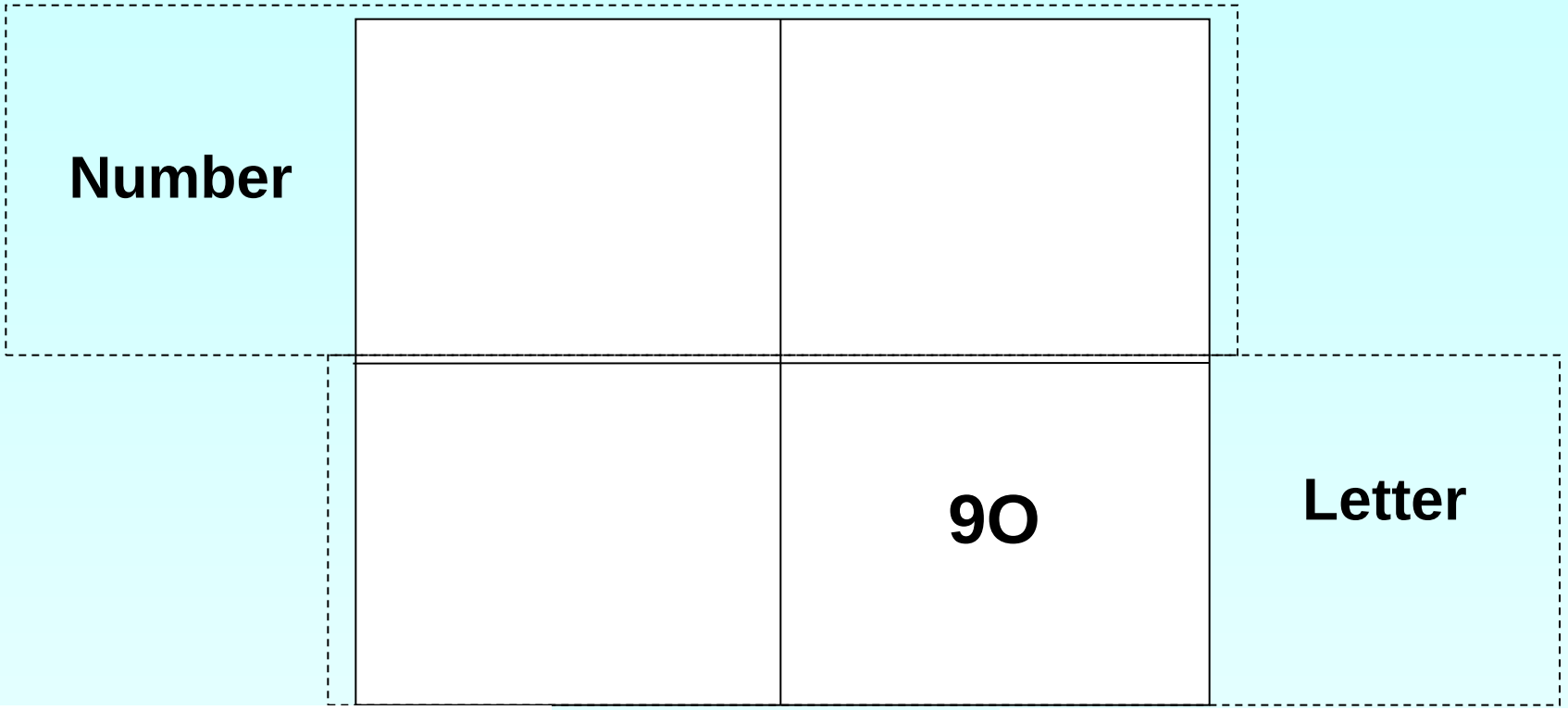

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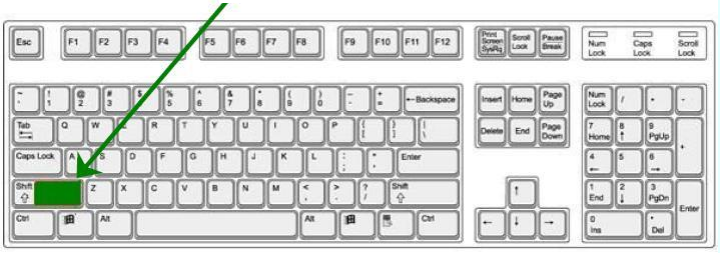
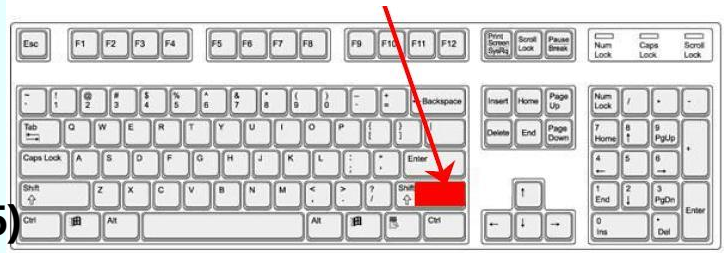
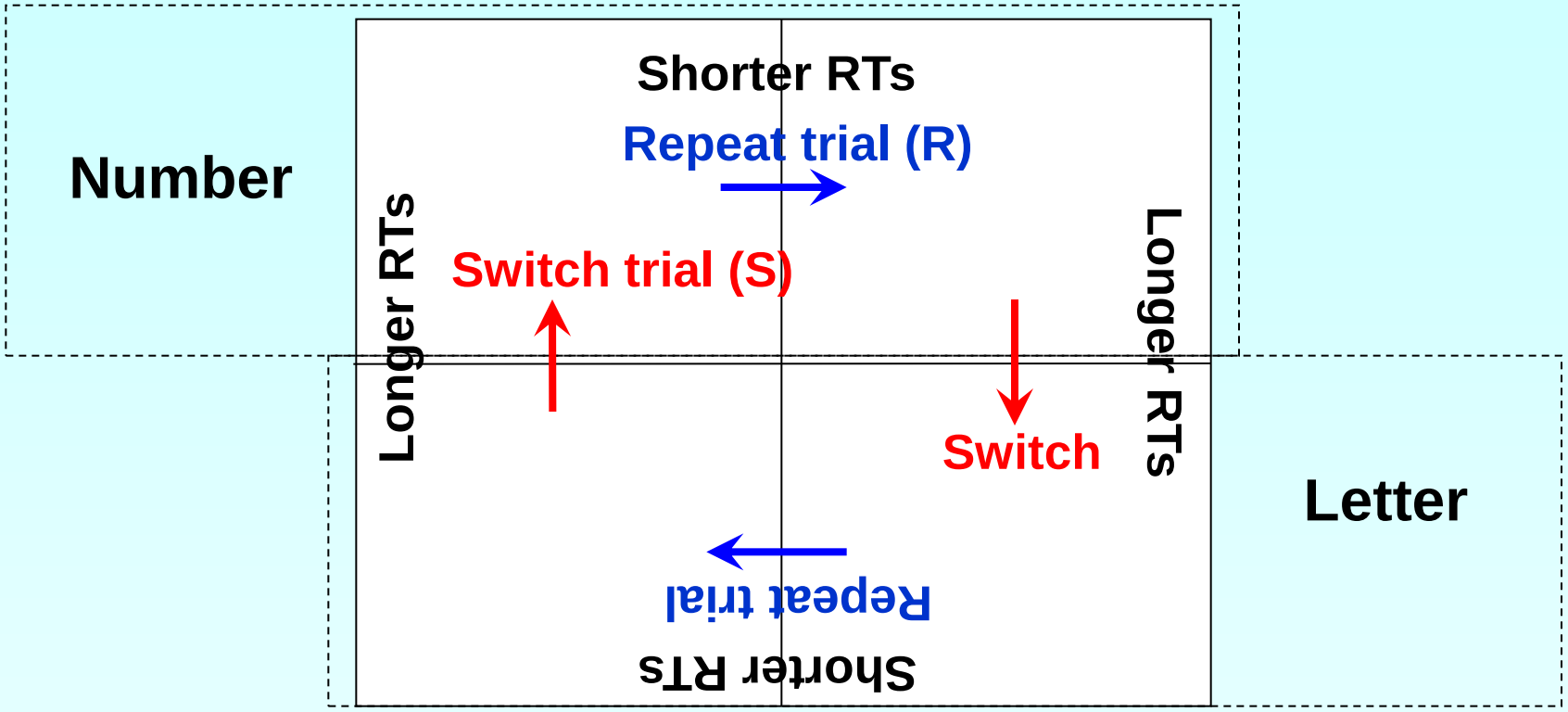




Rogers & Monsell (1995)

Example 1: task switching paradigm

Task-switching paradigm: measures



AC Measures: - Shift cost = Switch RTs - Repeat RTs

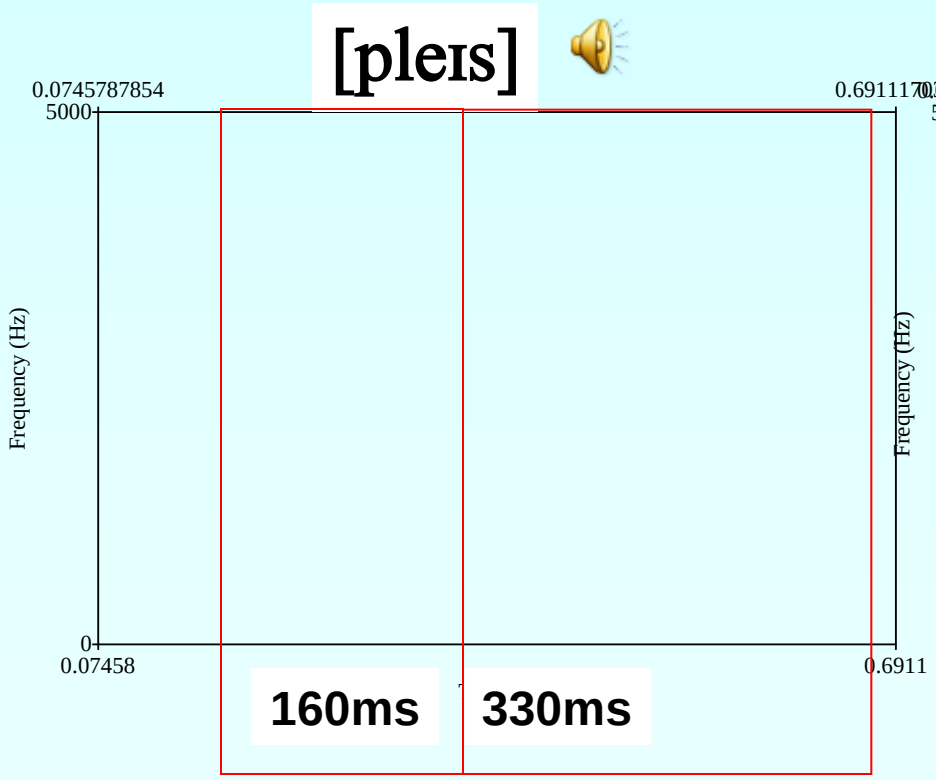
- Error rate = Switch trials + Repeat trials

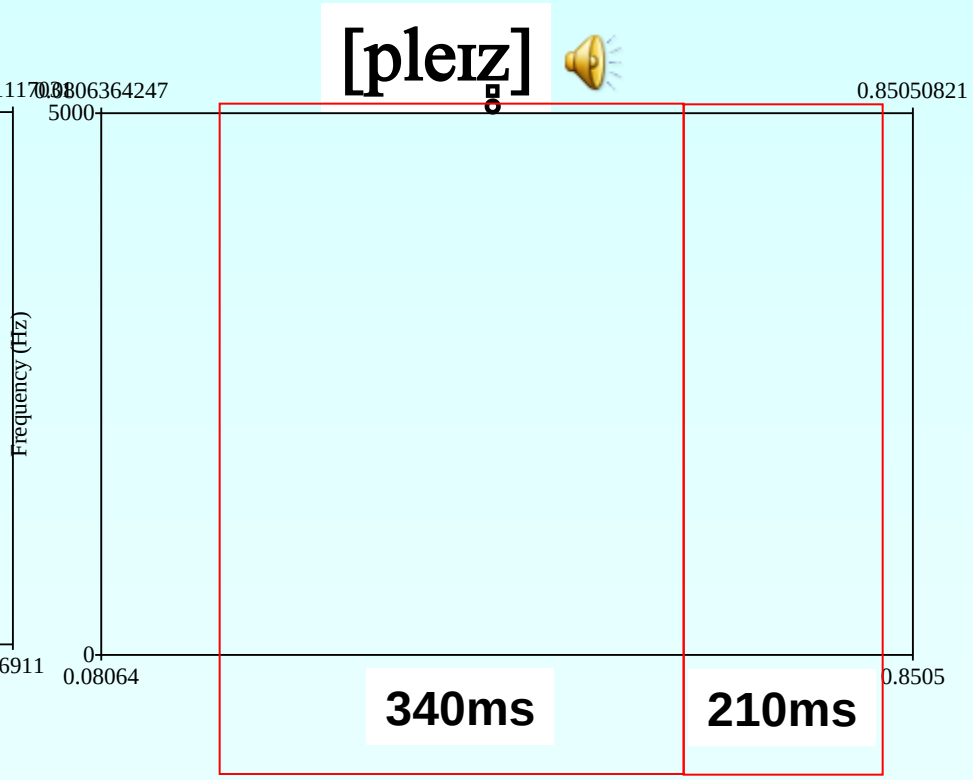
Example 1

Inhibition and attention in L2 speech perception

Attention control = foregrounding of duration (L2)

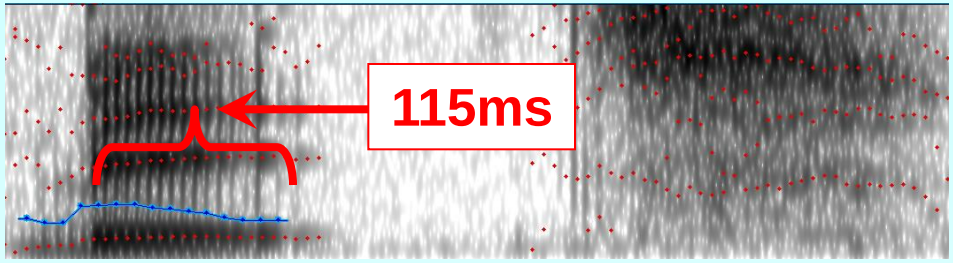
Inhibitory control = backgrounding of vocing (L1)



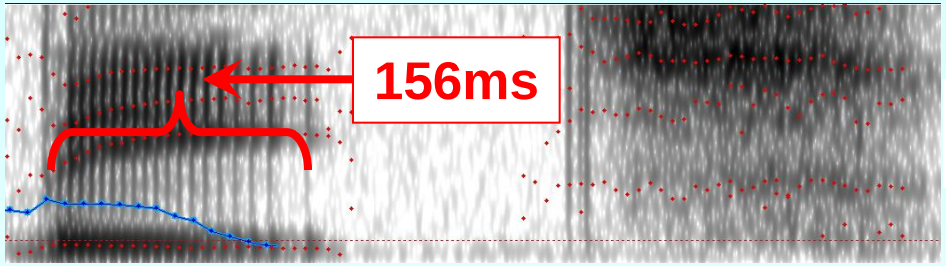


Example 1

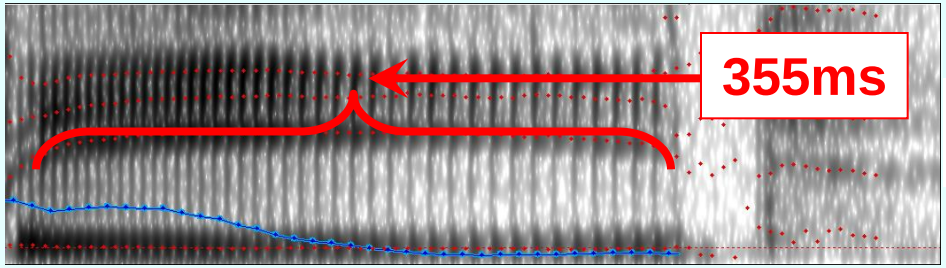
Foregrounding vs. backgrounding temporal and spectral information.



[bɪt]



[biːt]



[biːd]

Example 1: task switching paradigm (Attention Switching)

Inhibition and attention in L2 speech perception

Dimension 1: segmental duration (quantity)

(a) short: *i, e, a, etc.*

(b) long: *i, e, a, etc.*

Duration is used in English to encode voicing in word-final obstruents and at the same time is secondary to identifying vowel quality distinctions.

Dimesion 2: voice quality

(a) male: *i, e, a, etc.*

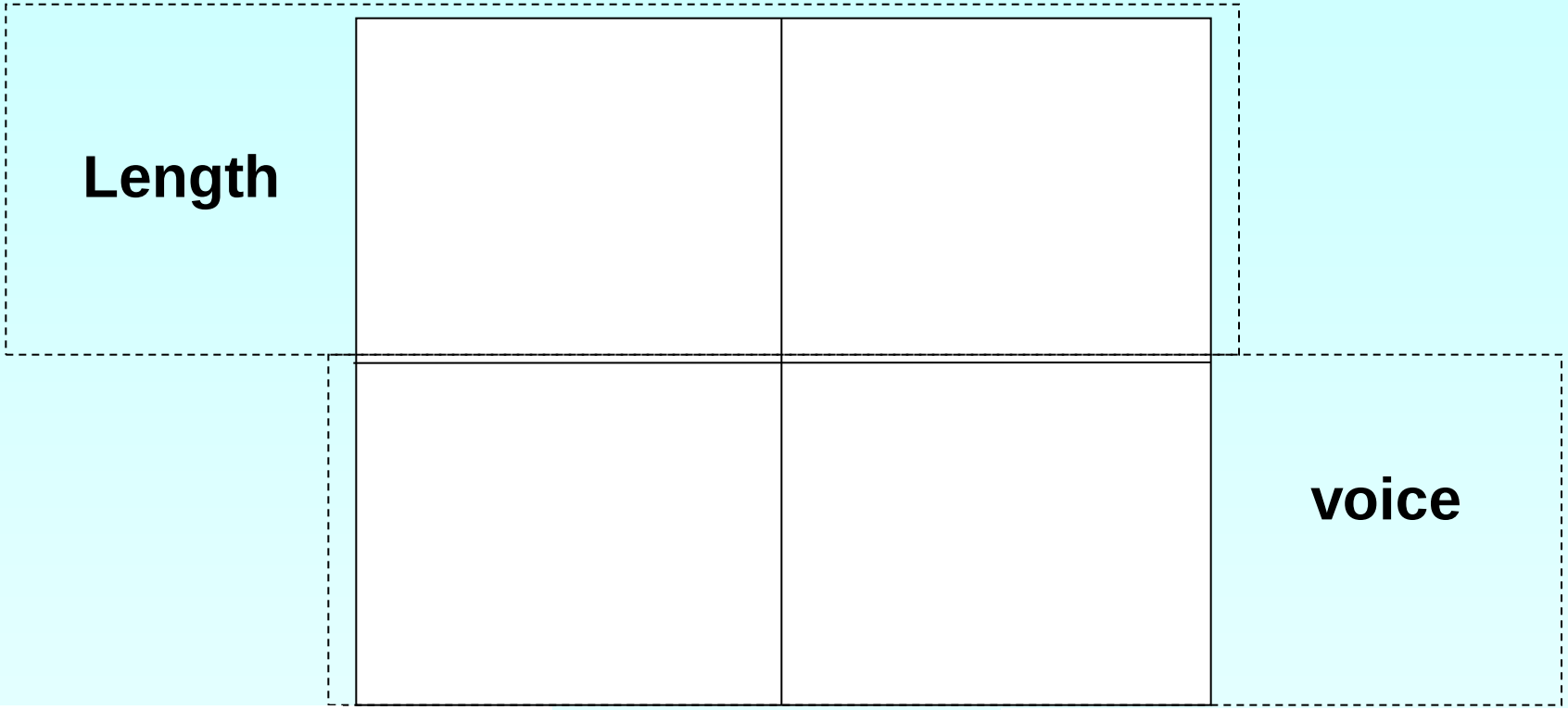
(b) female: *i, e, a, etc.*

Pitch is very important in speech. Besides identifying talkers on the basis of sex and age, pitch changes are used linguistically to convey meaning, as with intonation.

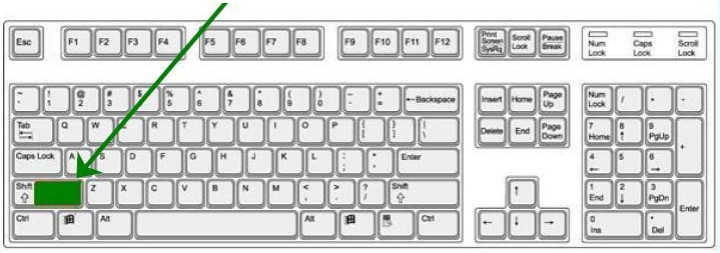
(Safronova & Mora 2013; Mora & Safronova, submitted)

Example 1: task switching paradigm

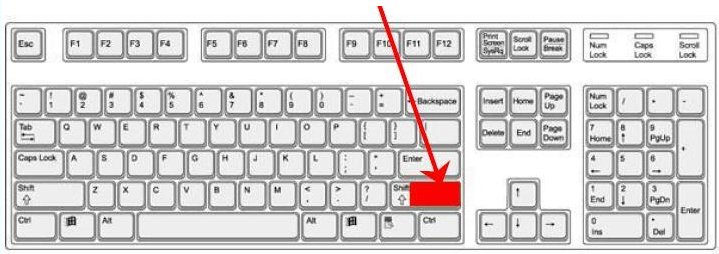
Task-switching paradigm (speech-based version)



Long Left key Female

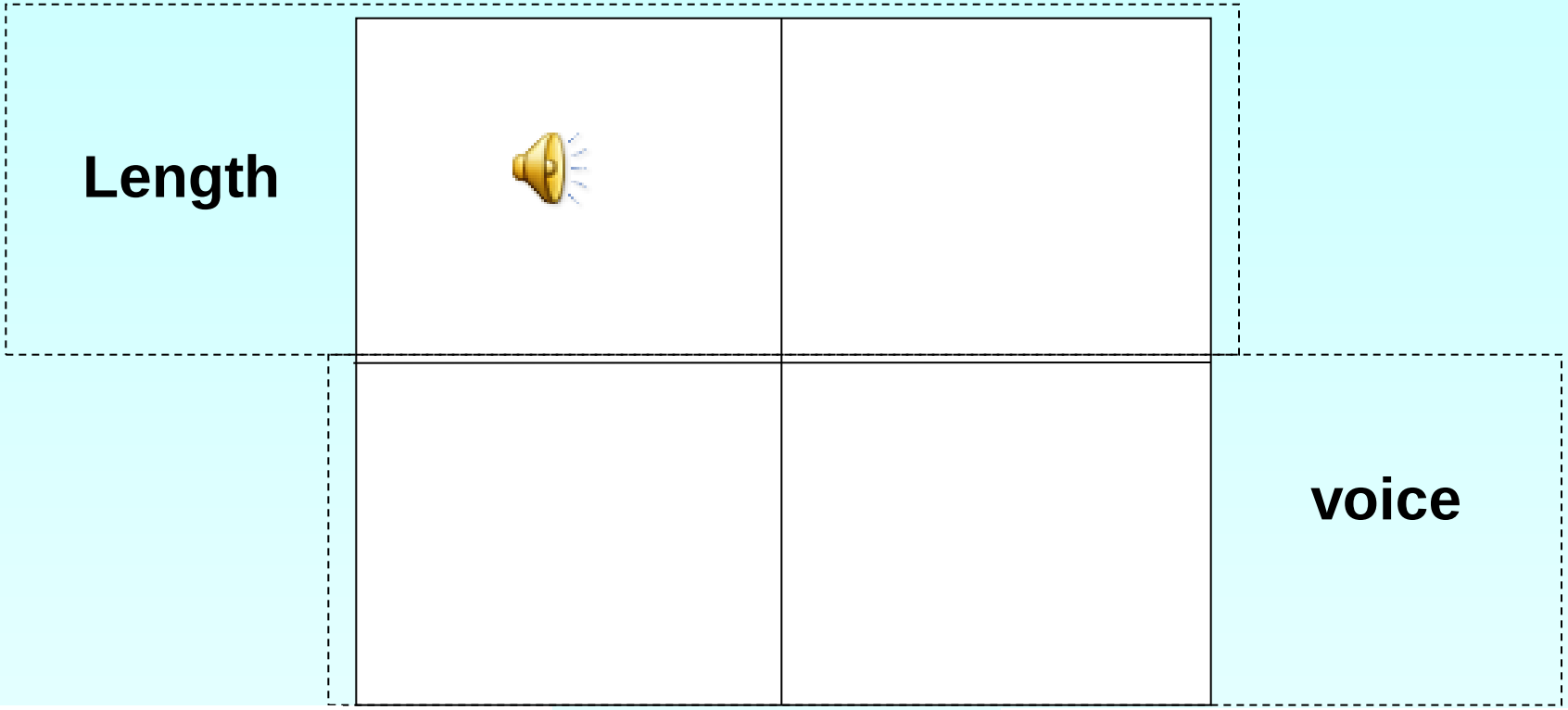


Short Right key Male

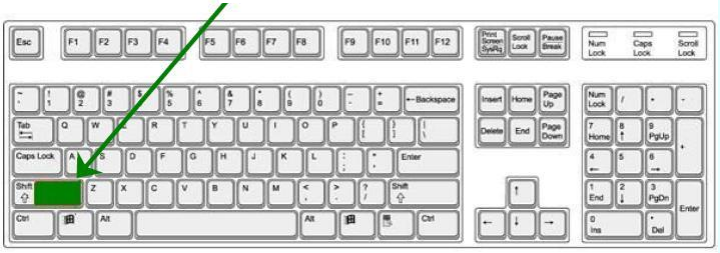


Example 1: task switching paradigm

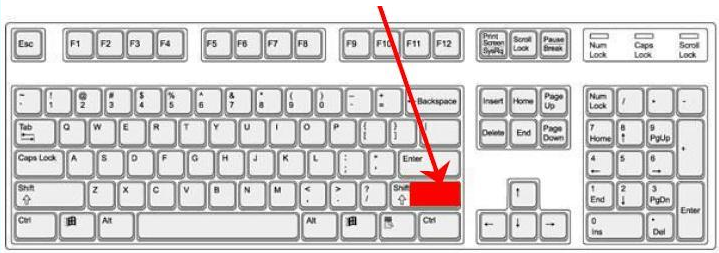
Task-switching paradigm (speech-based version)



Long **Left key** **Female**

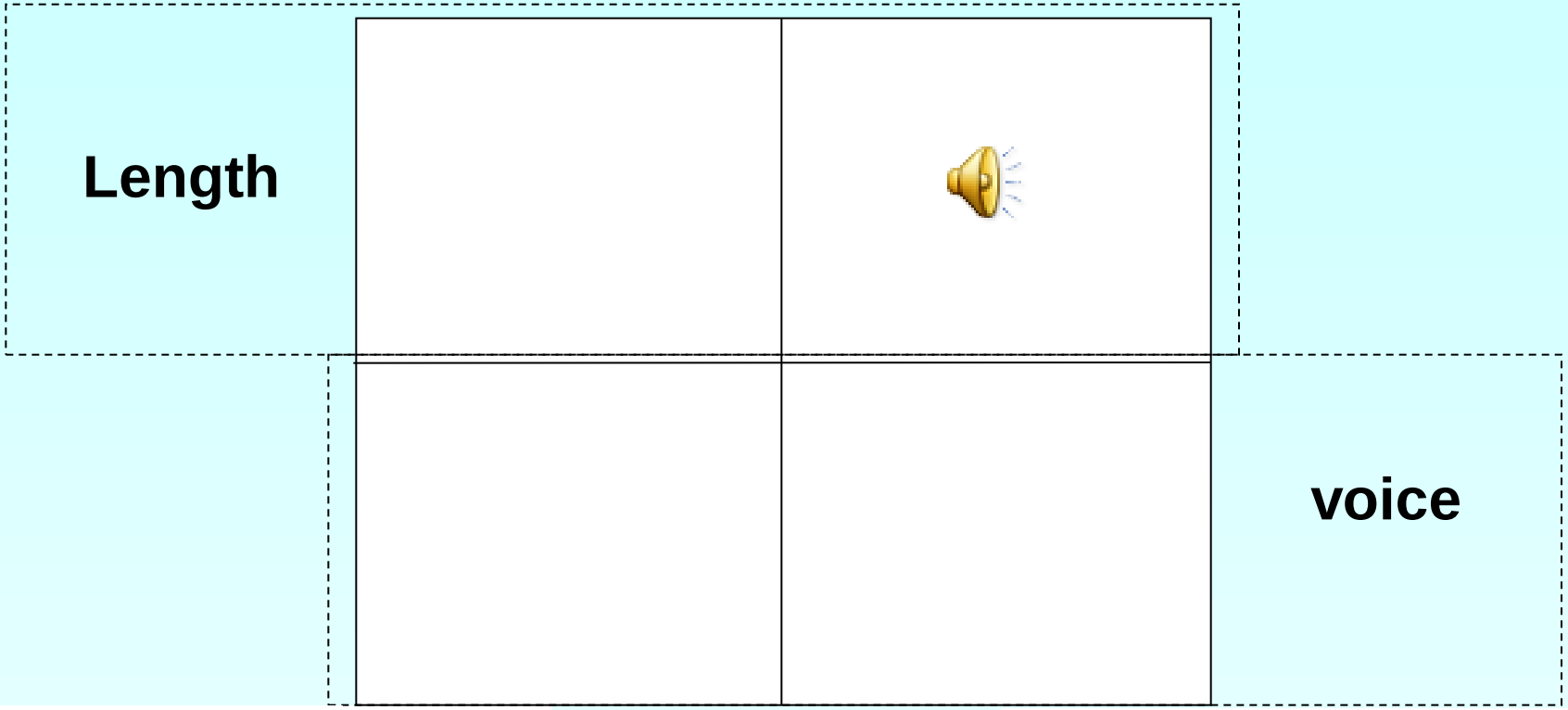


Short **Right key** **Male**

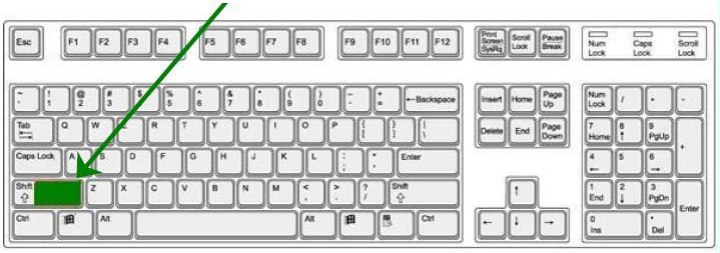


Example 1: task switching paradigm

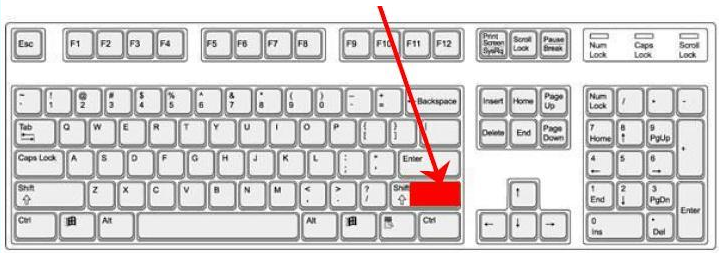
Task-switching paradigm (speech-based version)



Long Left key **Female**

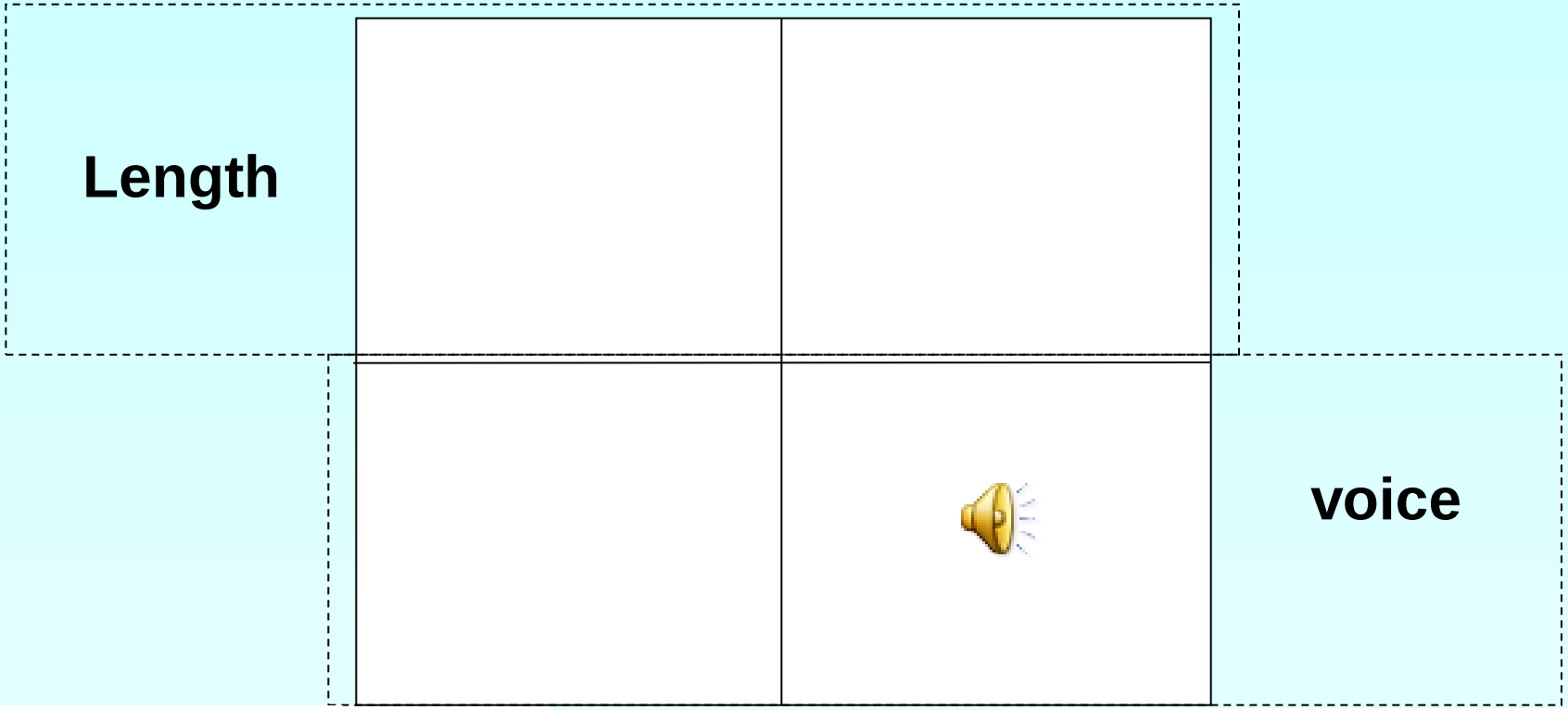


Short Right key **Male**

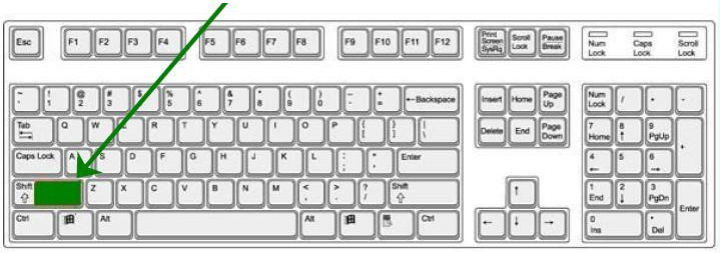


Example 1: task switching paradigm

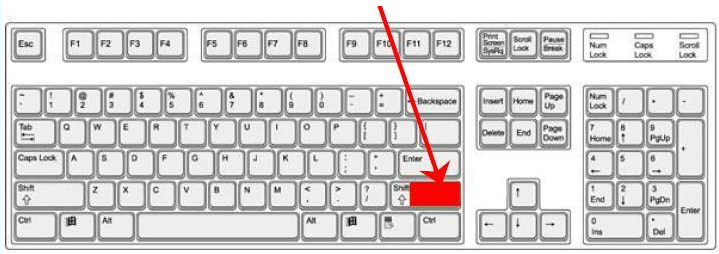
Task-switching paradigm (speech-based version)



Long Left key Female

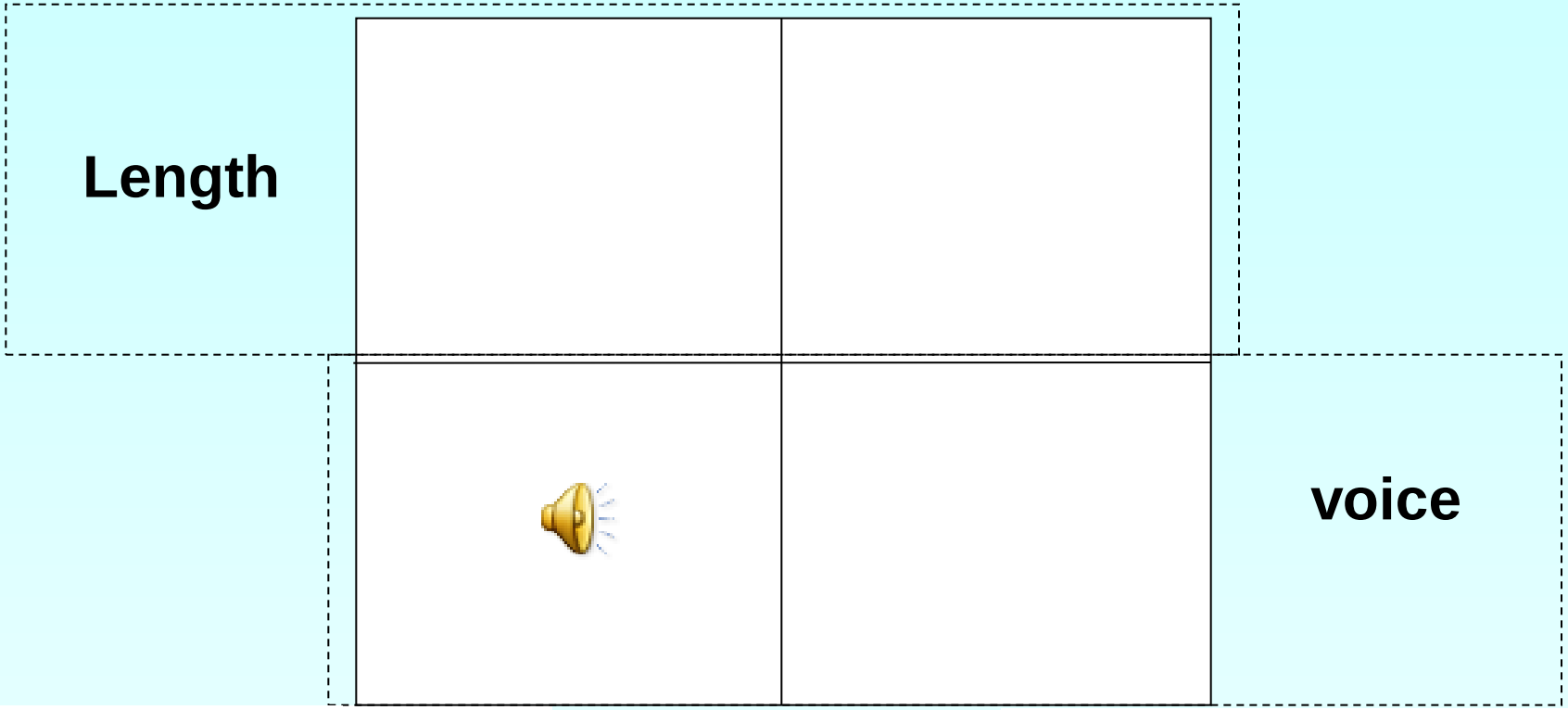


Short Right key Male

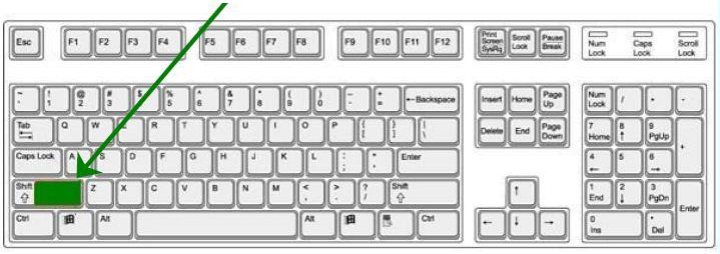


Example 1: task switching paradigm

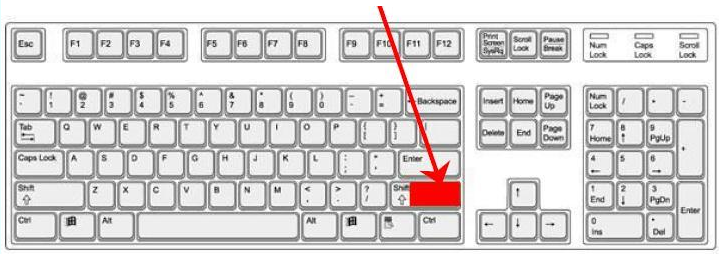
Task-switching paradigm (speech-based version)



Long Left key Female

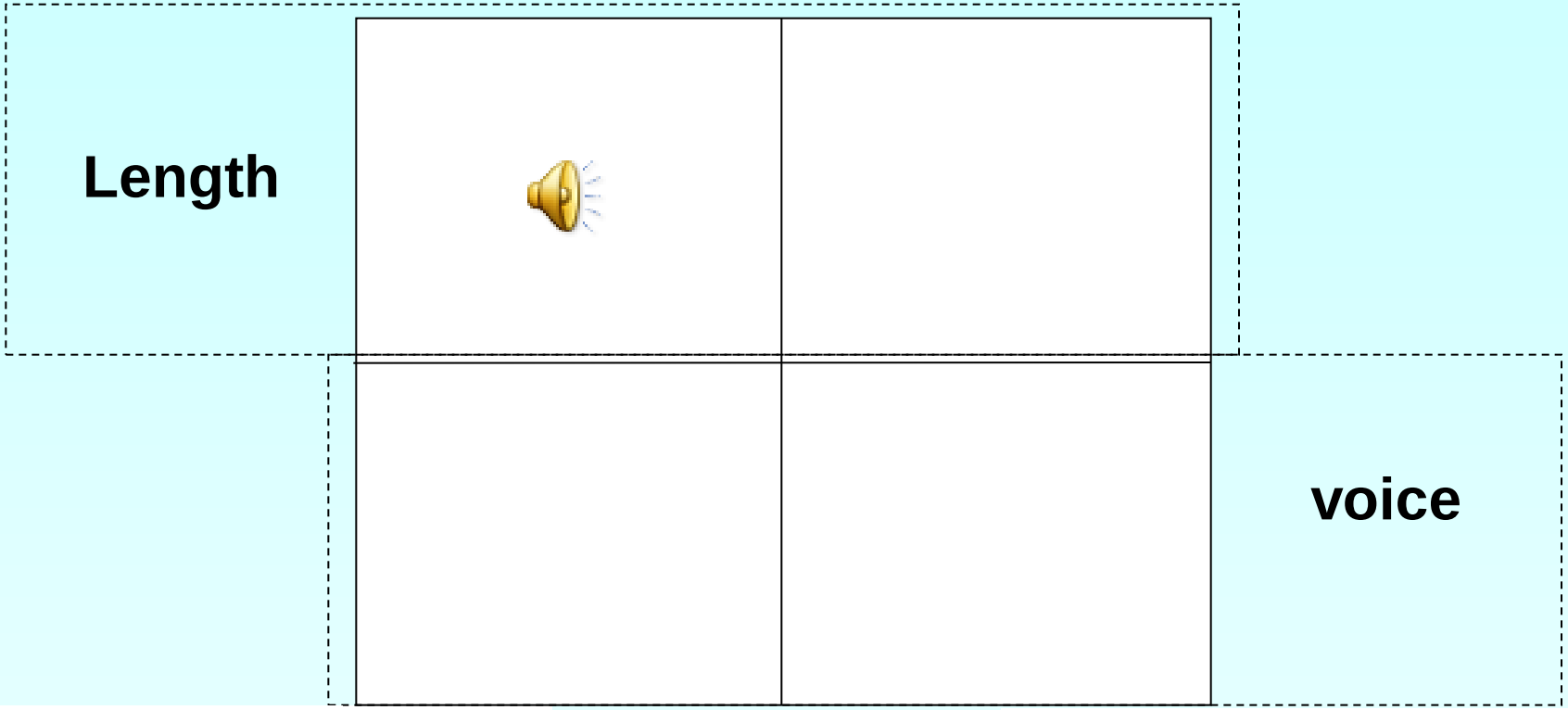


Short Right key Male

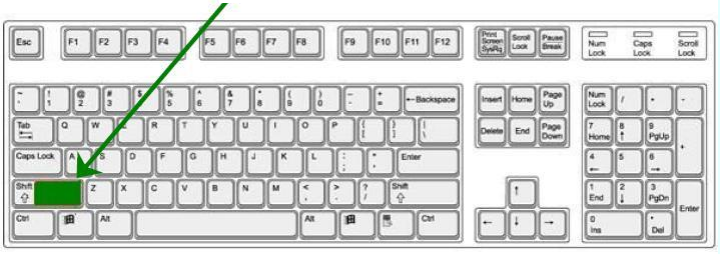


Example 1: task switching paradigm

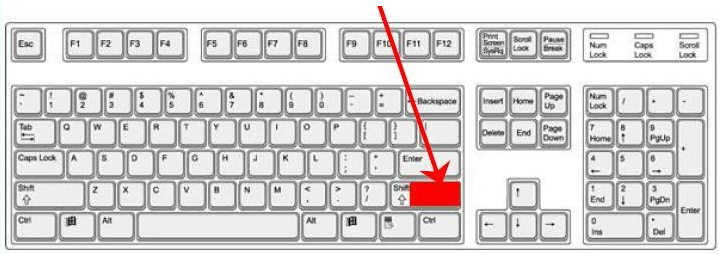
Task-switching paradigm (speech-based version)



Long Left key Female

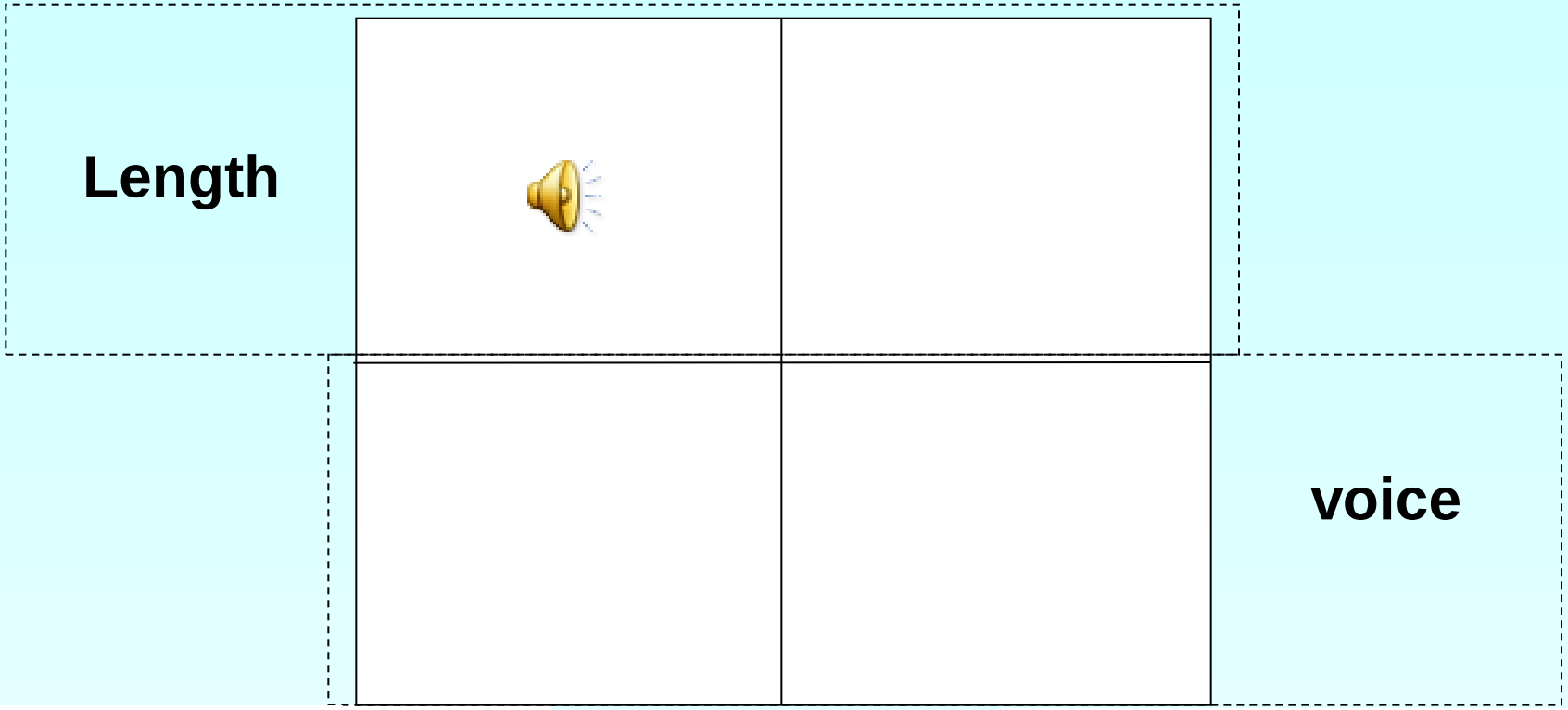


Short Right key Male

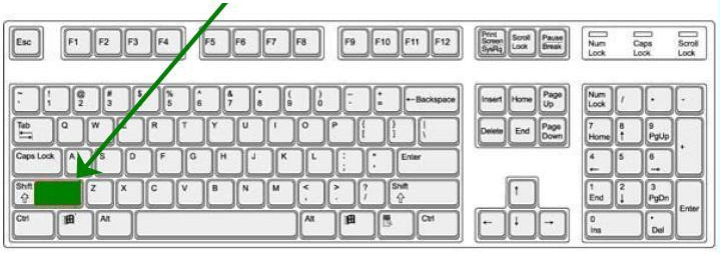


Example 1: task switching paradigm

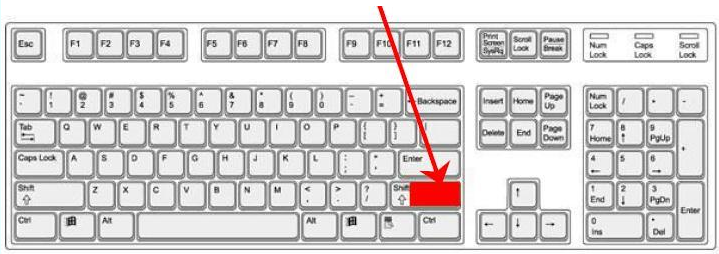
Task-switching paradigm (speech-based version)



Long Left key Female

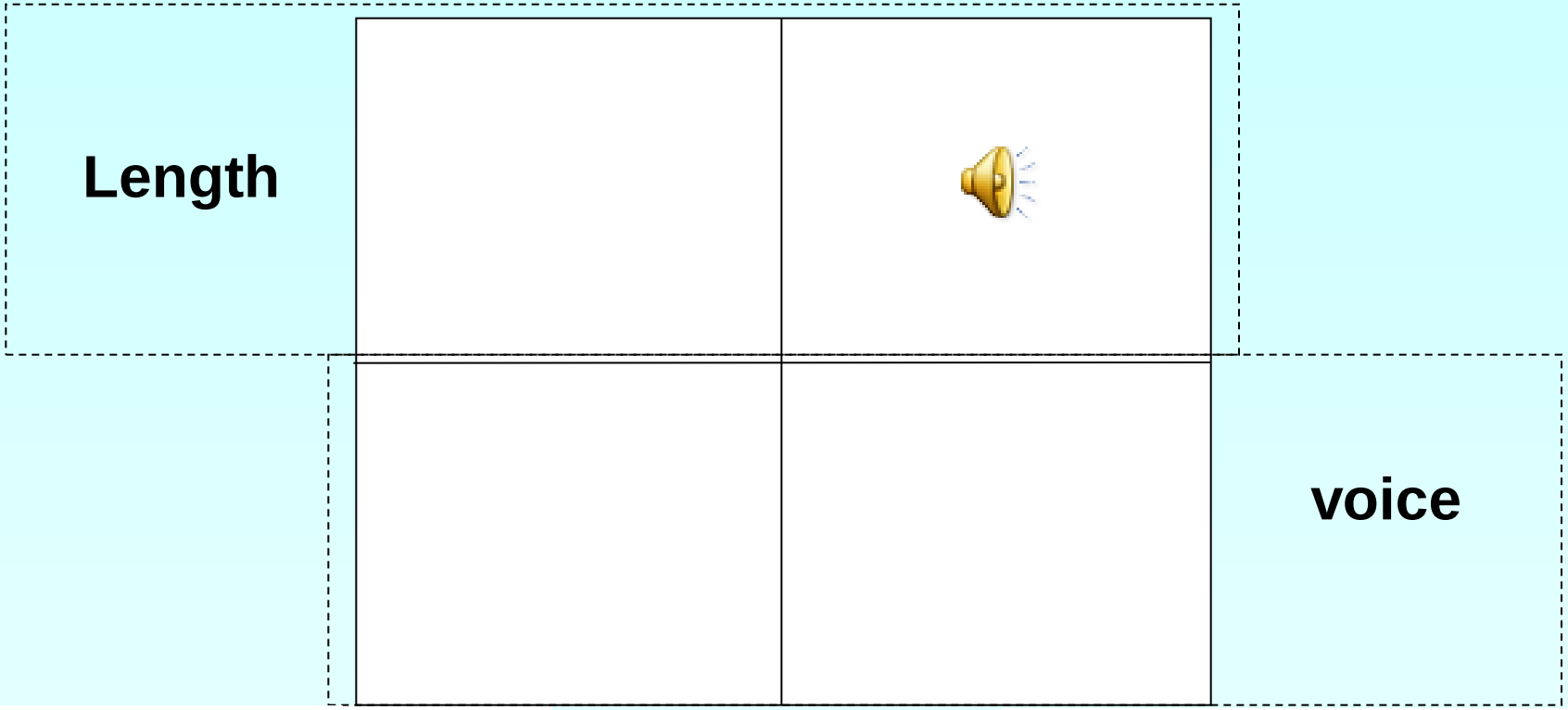


Short Right key Male

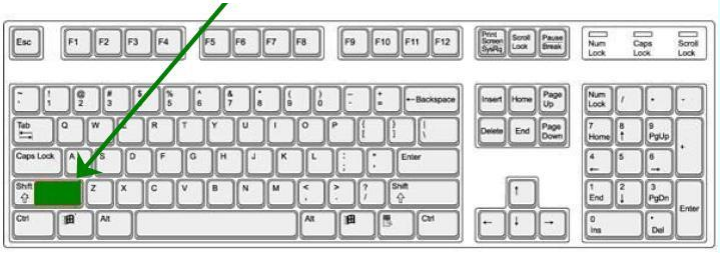


Example 1: task switching paradigm

Task-switching paradigm (speech-based version)



Long Left key Female



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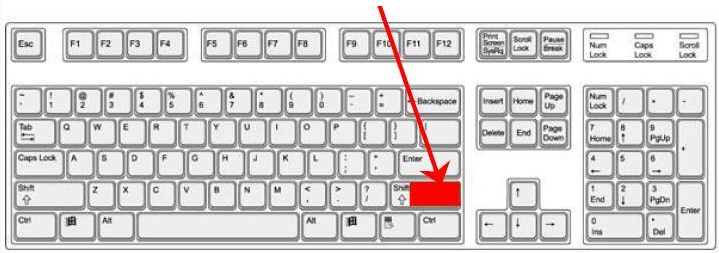
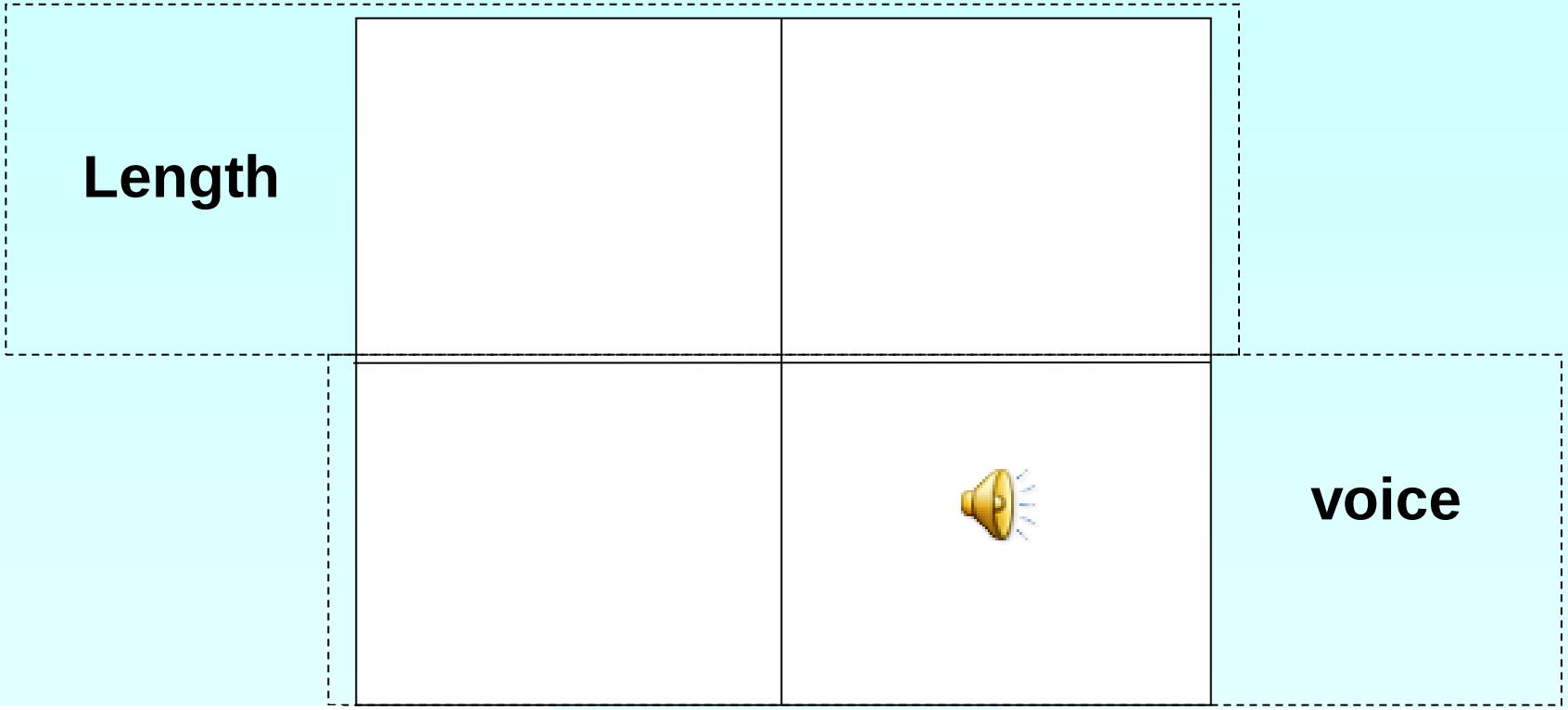
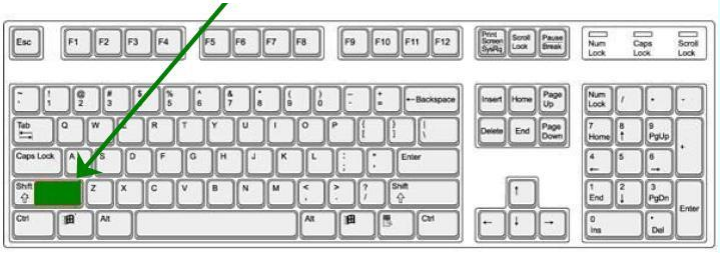


Example 1: task switching paradigm

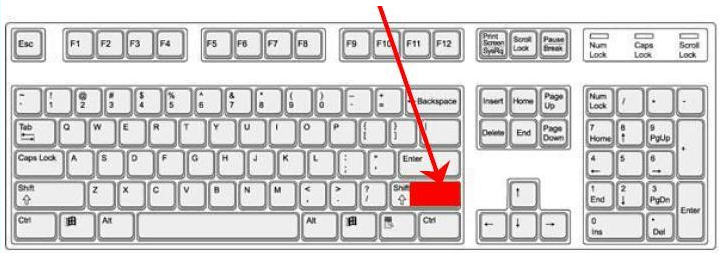
Task-switching paradigm (speech-based version)



Long Left key **Female**

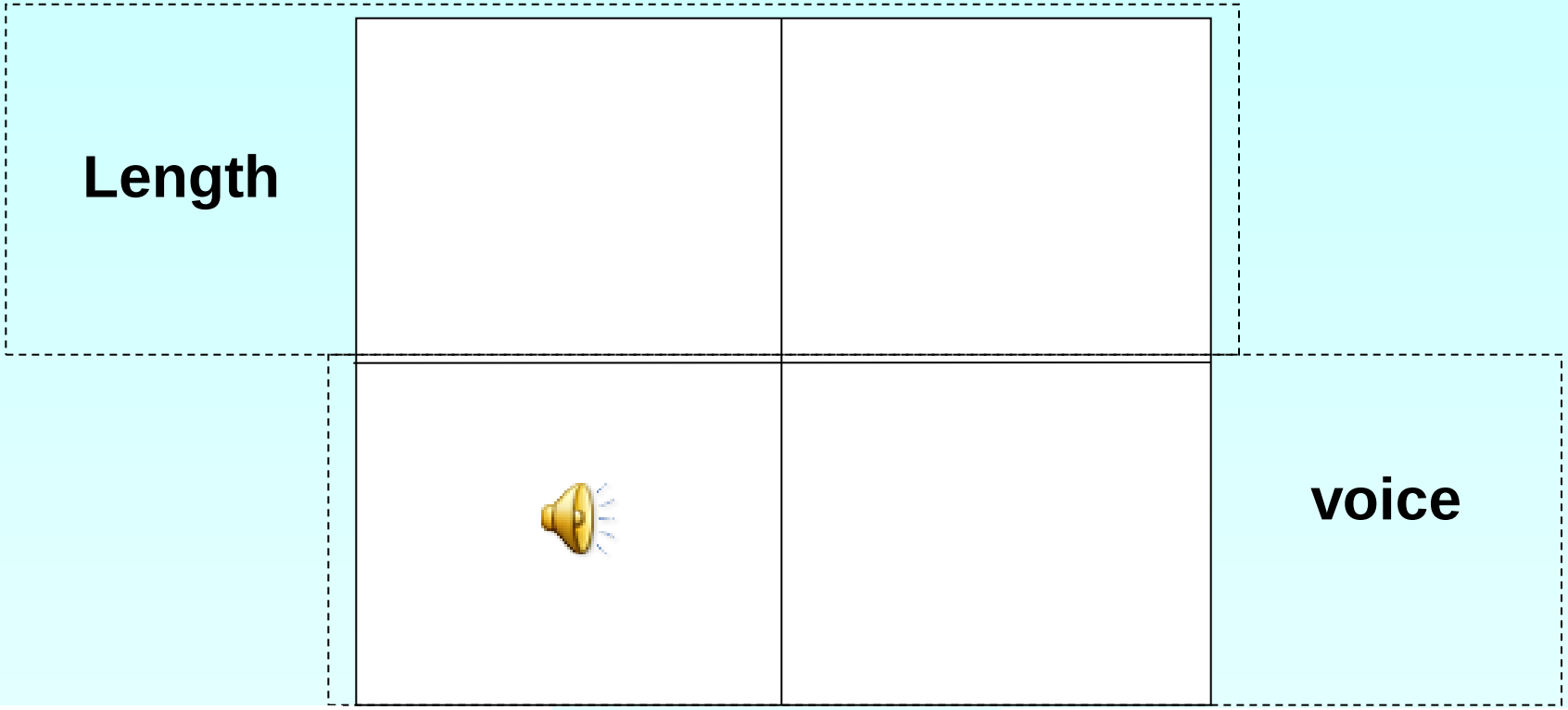


Short Right key **Male**

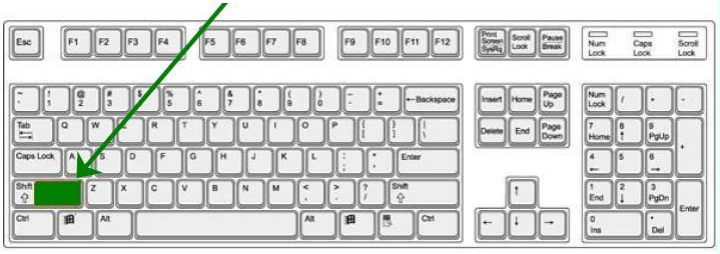


Example 1: task switching paradigm

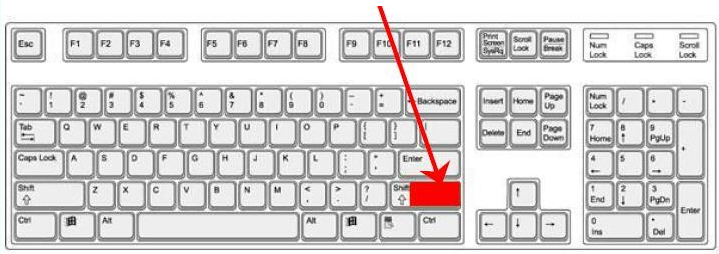
Task-switching paradigm (speech-based version)



Long Left key Female

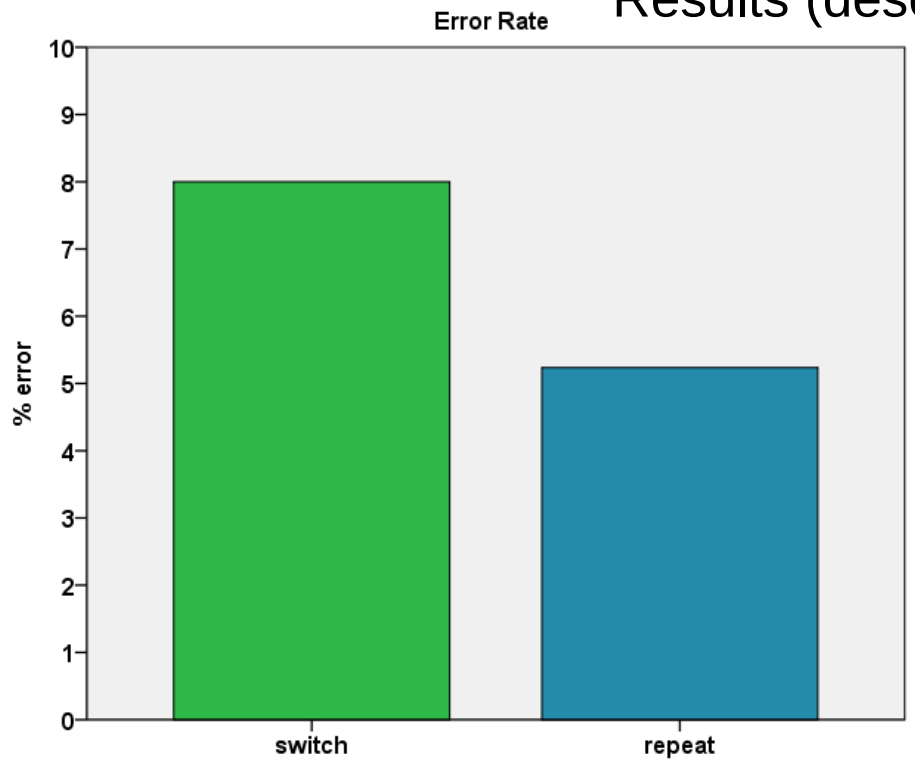


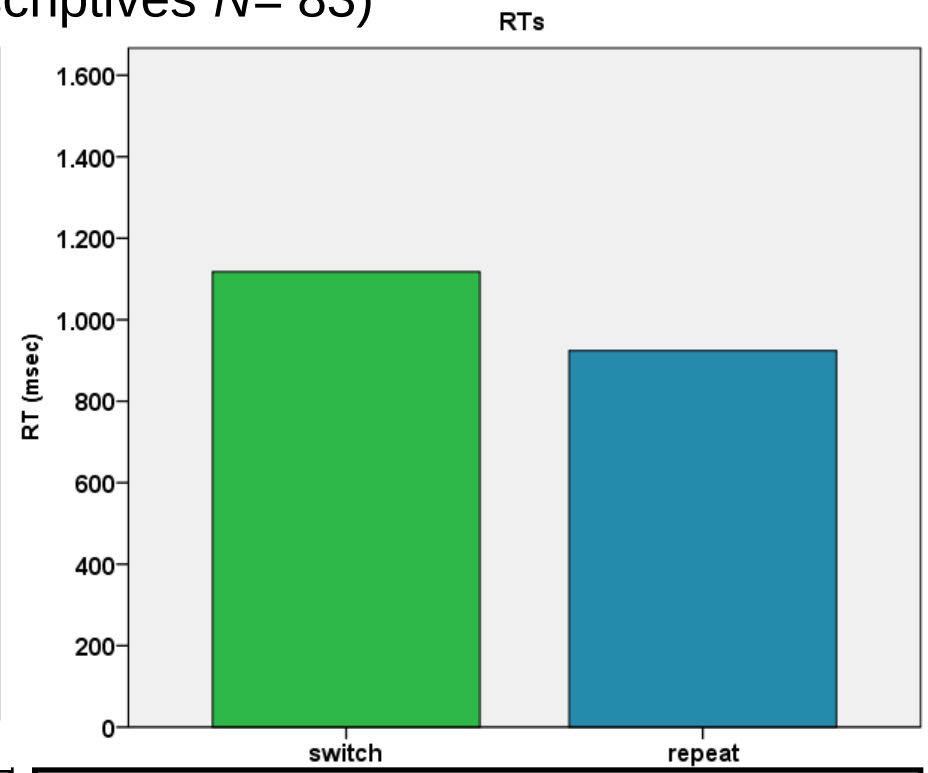
Short Right key Male



Example 1: task switching paradigm

Results (descriptives *N*= 83)





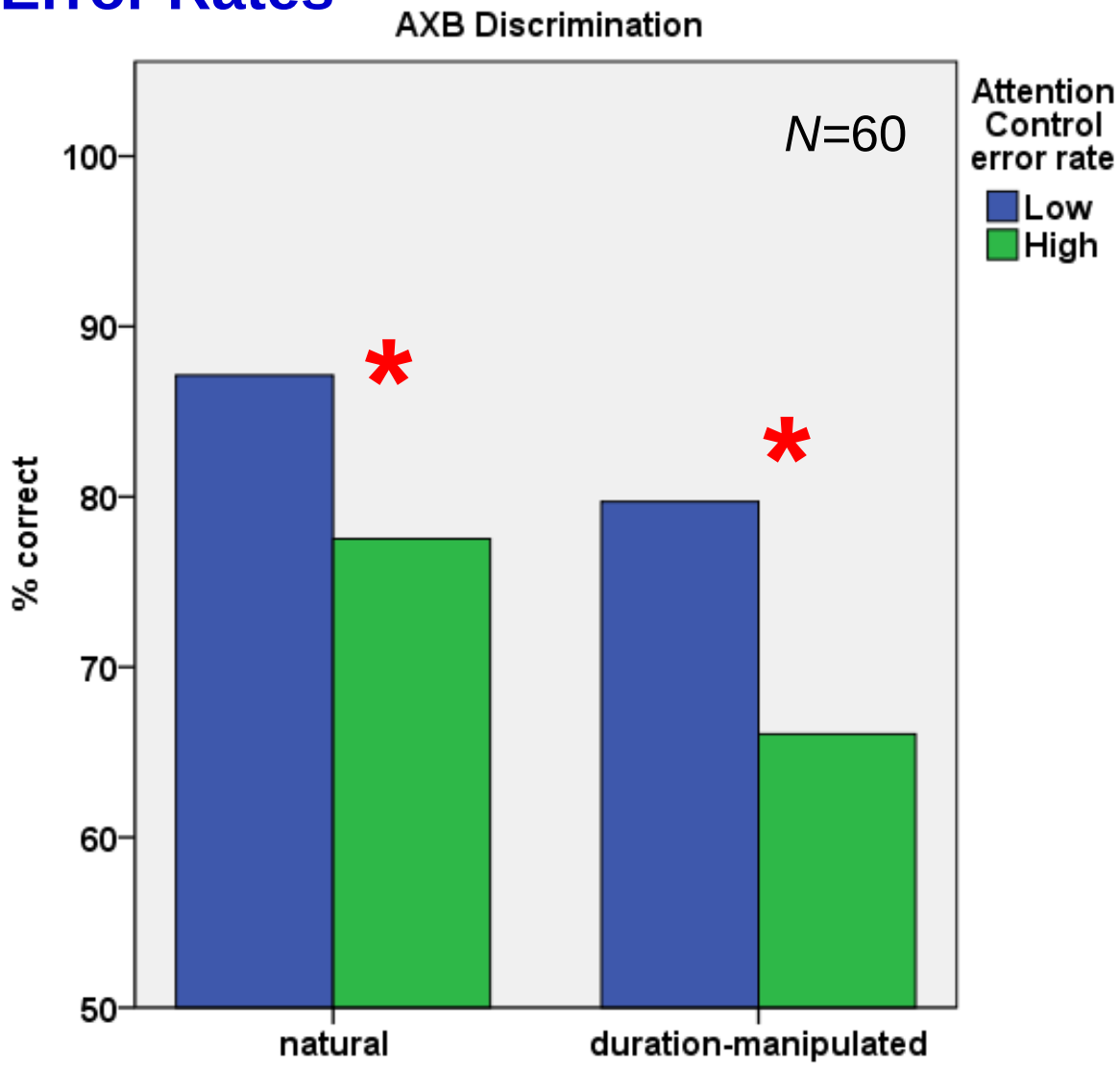
Error Rate (% ER)
Switch trials = 8.00
Repeat trials = 5.23

RTs
Switch RTs = 1117 ms
Repeat RTs = 923 ms
Switch cost = 193 ms

(Safronova & Mora, 2013)

Example 1: task switching paradigm

Error Rates



Pearson r	AC ER
DIS Nat	-.431**
DIS Man	-.476**

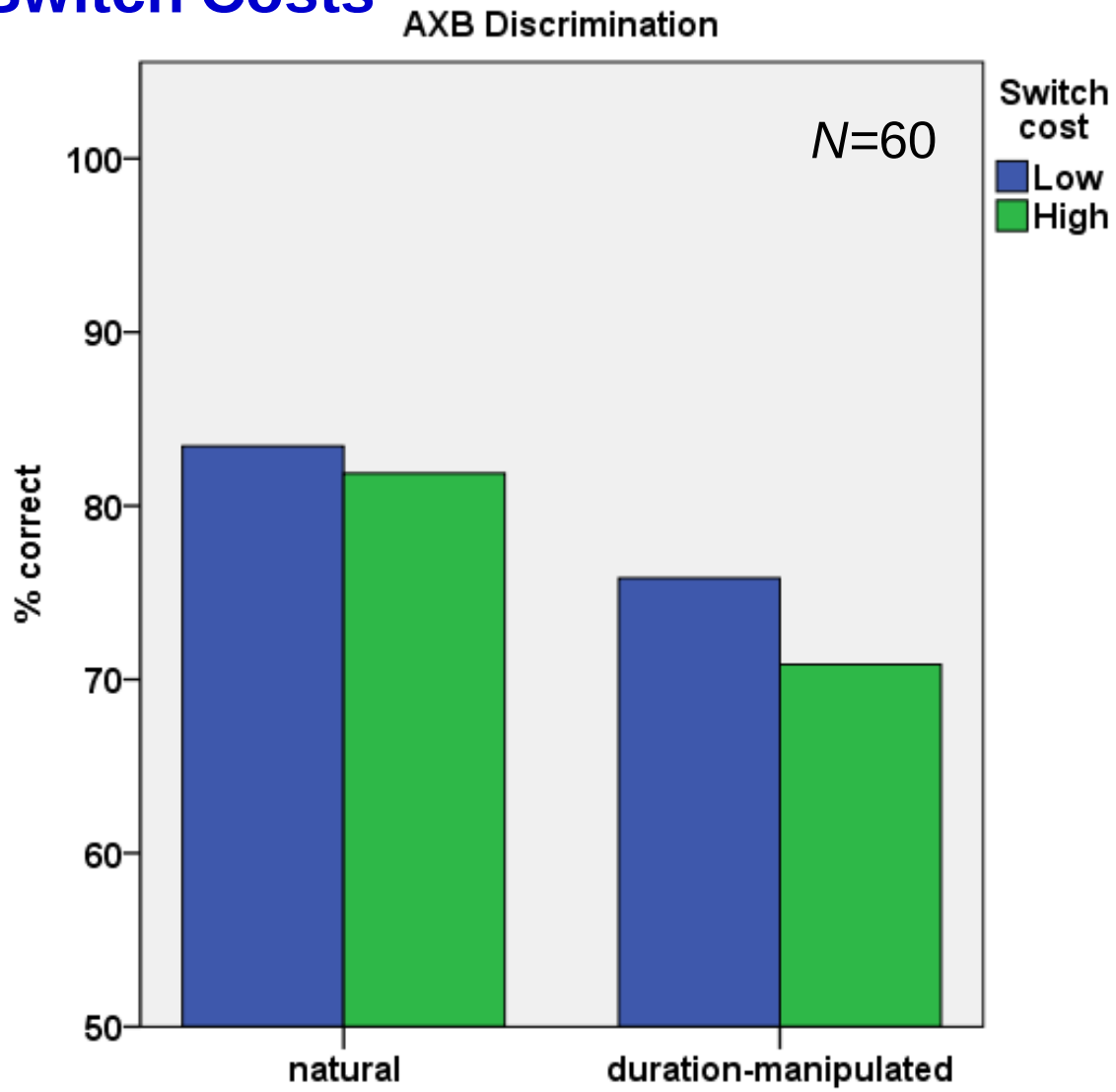
ANOVAs
within: Nat/Man ***p*<.001**
between: Low/High ***p*<.001**

Group differences:
Low AC ER (*N*=32)
High AC ER (*N*=28)
Nat: ***p*=.002**
Man: ***p*<.001**

(Safronova & Mora, 2013)

Example 1: task switching paradigm

Switch Costs



Pearson r	AC SC
DIS Nat n.s.	-.039
DIS Man n.s.	-.159

ANOVAs
within: Nat/Man *p*<.001
between: Low/High n.s.

Group differences:
Low AC SC (*N*=30)
High AC SC (*N*=30)
Nat: *p*=.572
Man: *p*=.209

(Safronova & Mora, 2013)

Example 2: bilingual picture naming task

Amount of inhibition = Level of proficiency

- In L1 activation is always high > strong inhibition
- In L2 activation is low (if proficiency is LOW) > little inhibition

Language switching paradigm

L1 L2

Trials: - switch (L1-L2 / L2-L1) and
non-switch (L1-L1 / L2-L2)
- language cued by background colour:

Measure: RTs from stimuli onset to voice-key activation

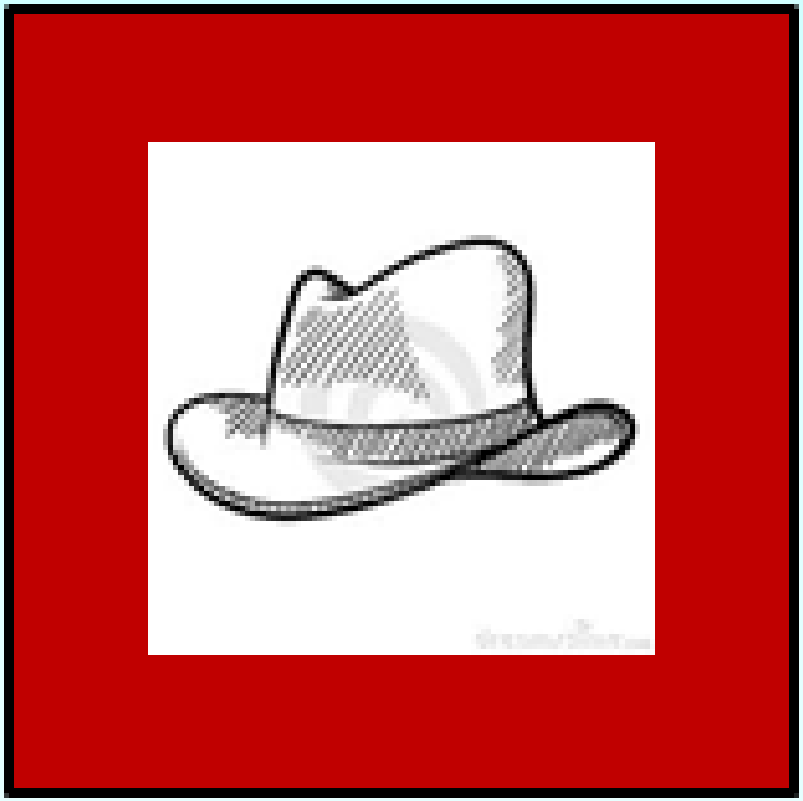
(Costa & Santesteban, 2004; Costa, Santesteban & Ivanova, 2006; Calabria et al. 2012)

Example 2: bilingual picture naming task

L1 L2

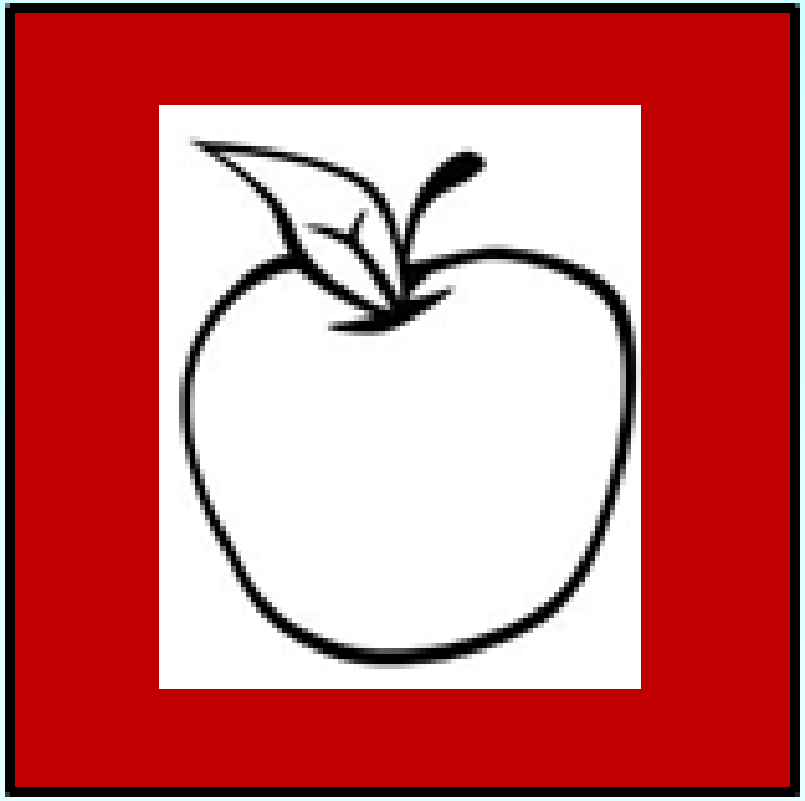
Example 2: bilingual picture naming task

L1 L2



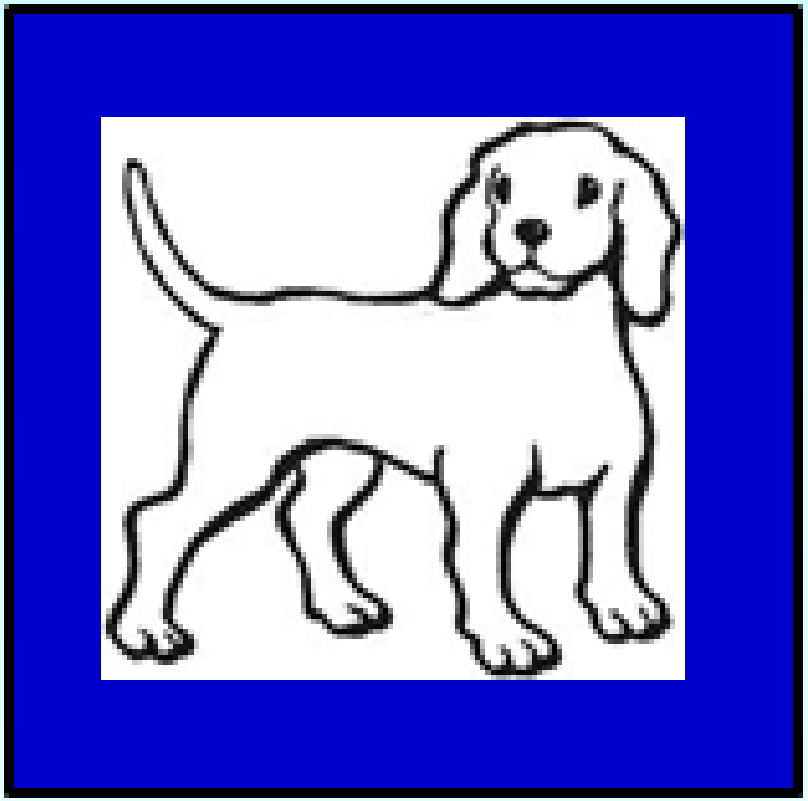
Example 2: bilingual picture naming task

L1 L2



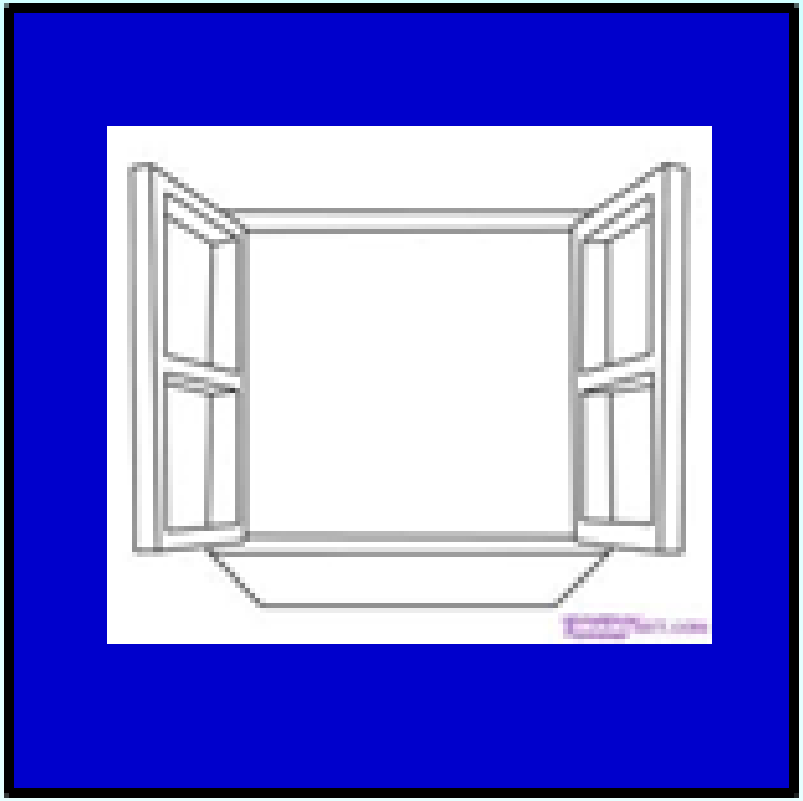
Example 2: bilingual picture naming task

L1 L2



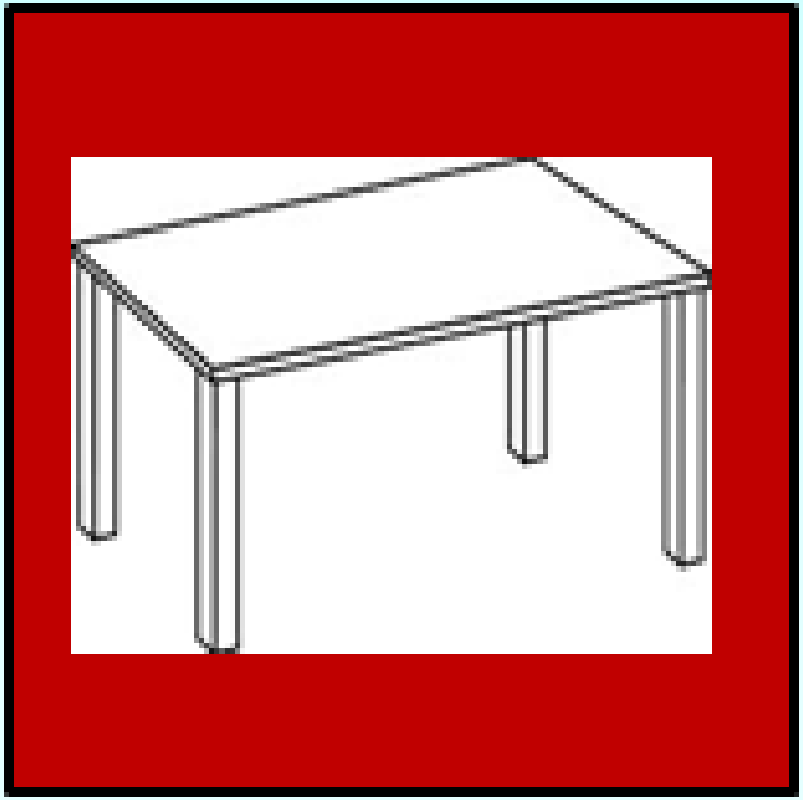
Example 2: bilingual picture naming task

L1 L2



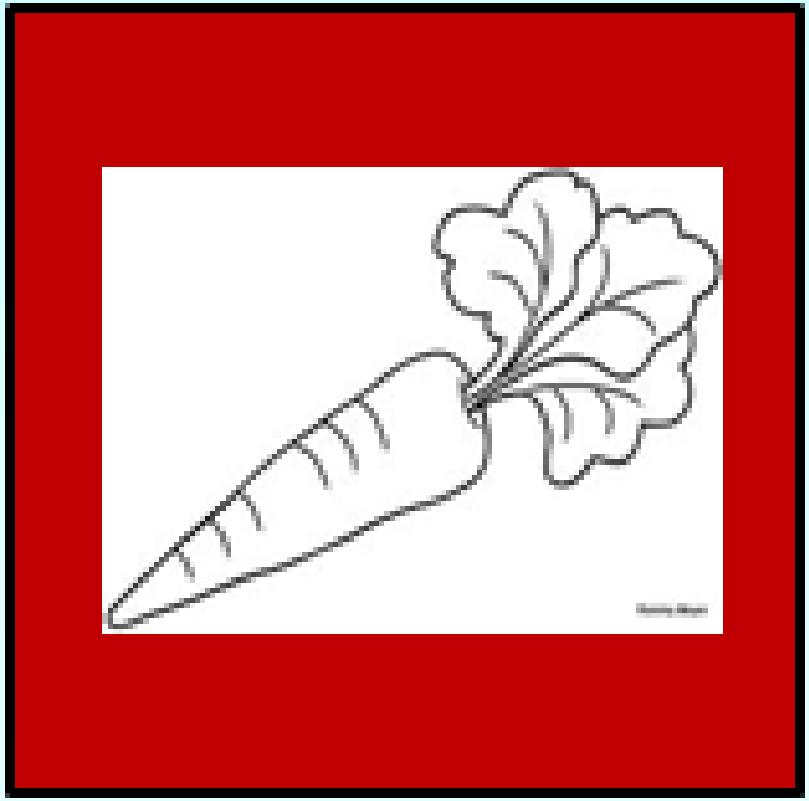
Example 2: bilingual picture naming task

L1 L2



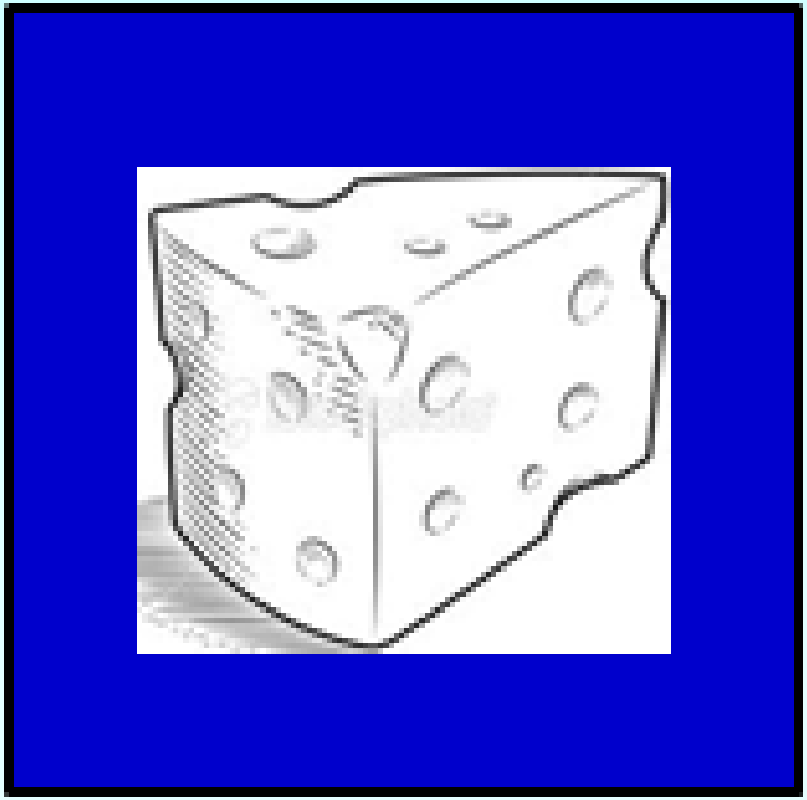
Example 2: bilingual picture naming task

L1 L2



Example 2: bilingual picture naming task

L1 L2



Example: word retrieval in a bilingual picture naming task

Amount of inhibition = Level of proficiency

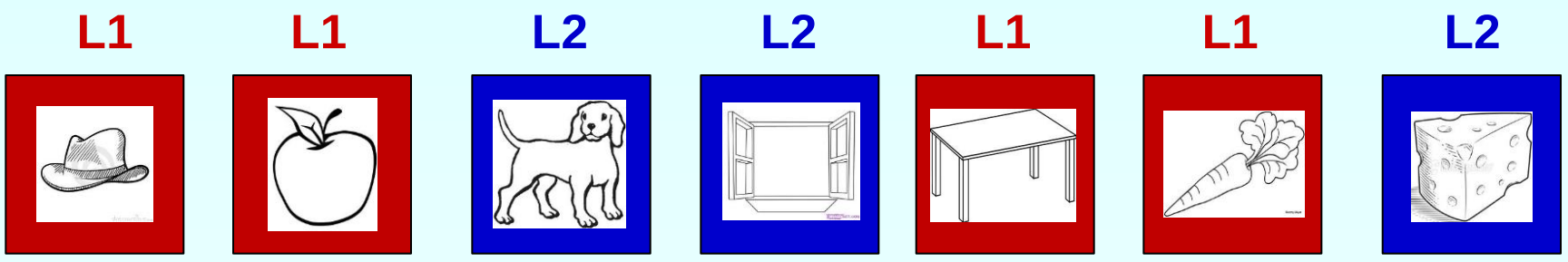
- In L1 activation is always high > strong inhibition
- In L2 activation is low (if proficiency is LOW) > little inhibition

Language switching paradigm

Trials: - switch (L1-L2 / L2-L1) and non-switch (L1-L1 / L2-L2)

- language cued by background colour: L1 L2

Measure: RTs from stimuli onset to voice-key activation

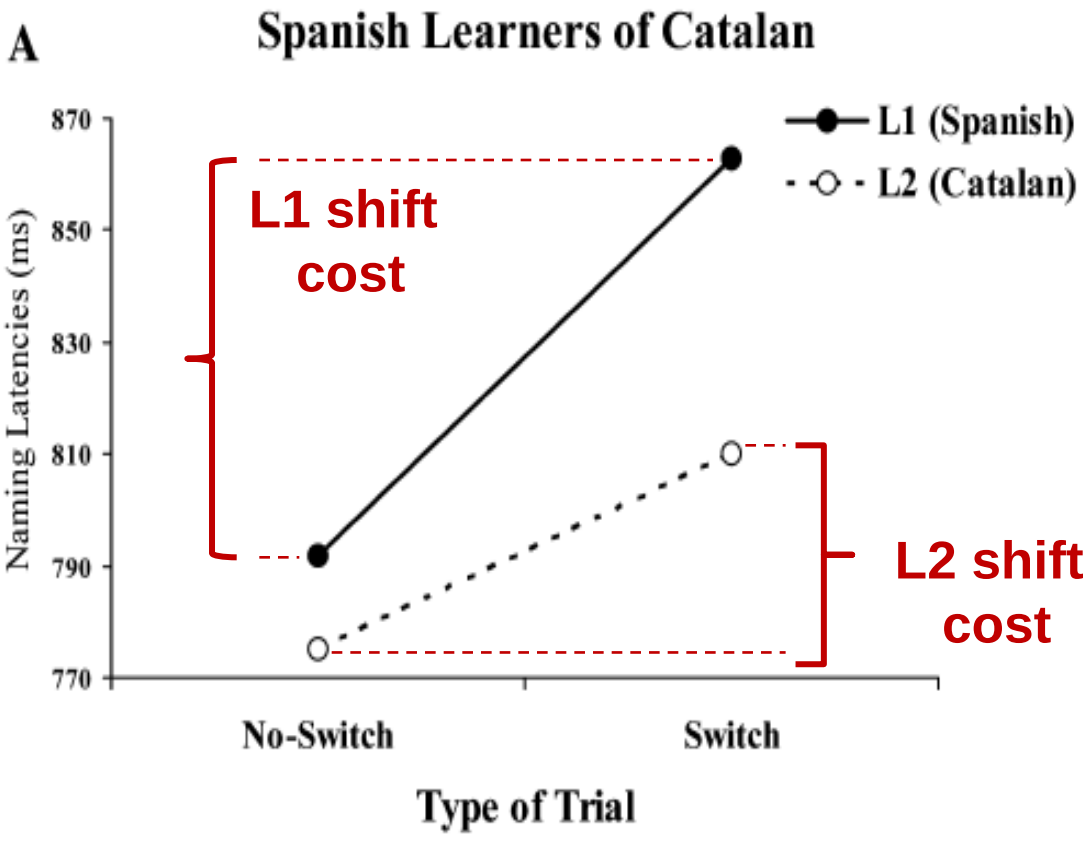


(Costa & Santesteban, 2004; Costa, Santesteban & Ivanova, 2006; Calabria et al. 2012)

Inhibition and L2 phonology

Amount of inhibition is related to proficiency level

- **Activation HIGH in L1** **> strong inhibition**
- **Activation LOW in L2 (if proficiency is LOW)** **> little inhibition**



- **RTs are higher in Switch than in No-Switch trials.**

- **L1-to-L2 and L2-to-L1 switching costs are asymmetrical:**

> shifting to L1 requires more time (to overcome inhibition)

(Costa & Santesteban, 2004; Costa, Santesteban & Ivanova, 2006; Calabria et al. 2012)

Inhibition and L2 phonology

Amount of inhibition = Level of proficiency

- **Activation HIGH in L1** **> strong inhibition**
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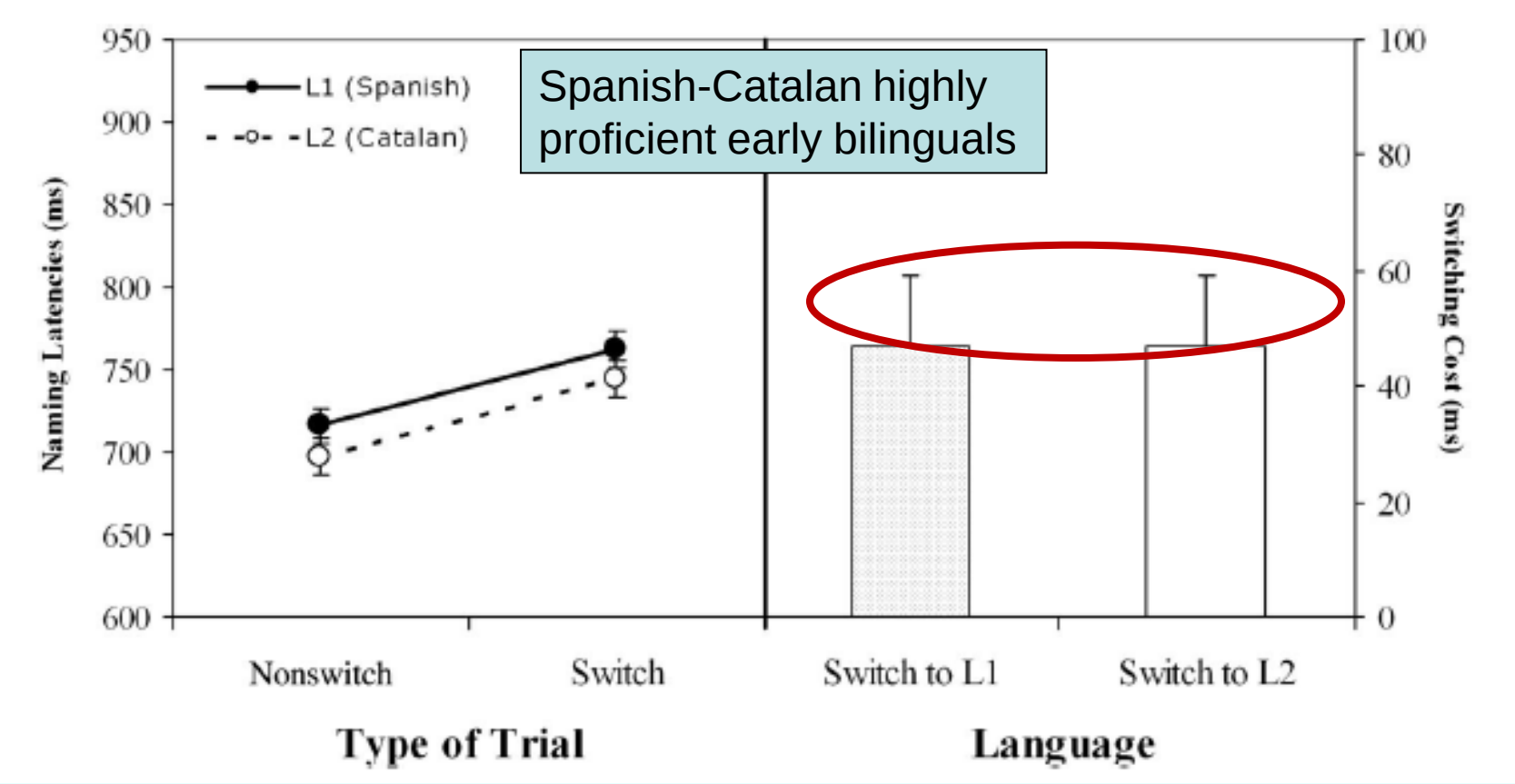


(Costa & Santesteban, 2004; Costa, Santesteban & Ivanova, 2006; Calabria et al. 2012)

Inhibition and L2 phonology

Lev-Ari & Peperkamp (2013)

Bilinguals with lower inhibitory skill exhibit greater influence of the second language on the first.

- 30 Late English-French bilinguals
- Highly proficient in both languages
- Used both languages daily
- L1 (English)-dominant
- Residing in France for at least 3 years (range: 4–49, Median=17, SD=15.4)

They produced and perceived Voice Onset Time of voiceless stops (/p t k/) in English in a more French-like manner, the lower their inhibitory skill was.

(Lev-Ari & Peperkamp 2013)

Inhibition and L2 phonology: Example 3 (cognitive task)

Inhibitory control

Retrieval-induced inhibition task:

Individual measures of inhibitory control obtained by inducing the decrease of activiation of competing lexical items during lexical retrieval

- NOT the deliberate, controlled suppression of a response (unlike Stroop or Simon tasks**).**

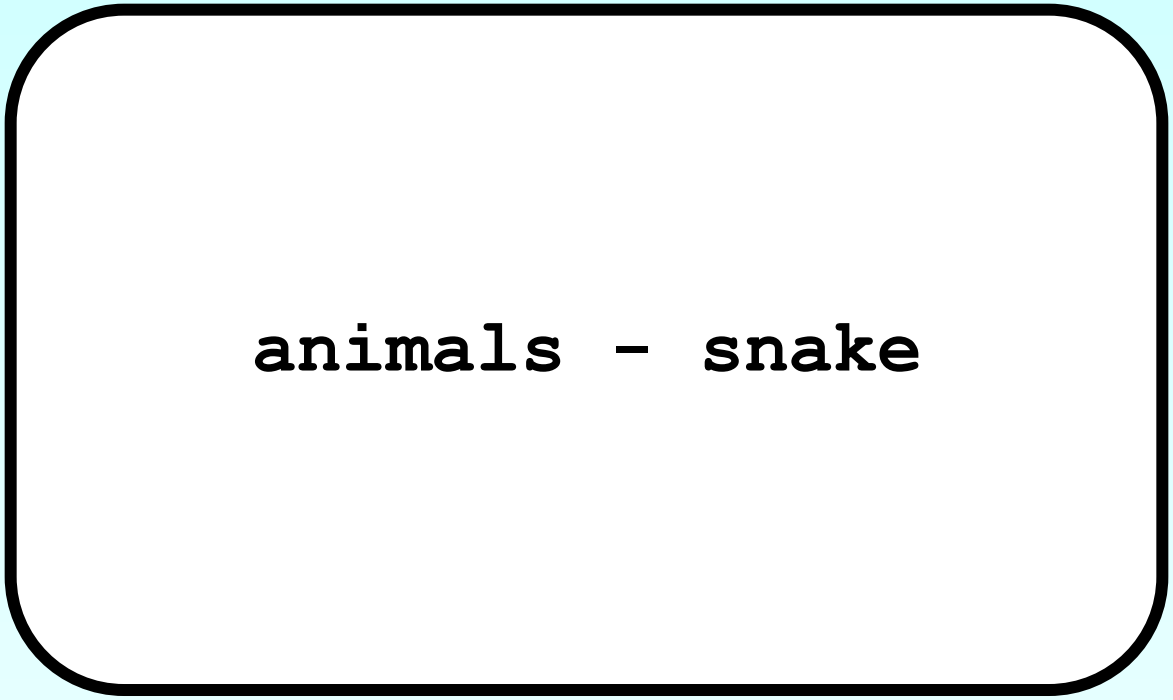
- Based on spreading activation/ connectionist networks models:

Decrease in activation = negative activation
=negative connection weights.

(Lev-Ari & Peperkamp 2013)

Example 3: retrieval-induced inhibition

Memorize **Practice** **Recognize**



Example 3: retrieval-induced inhibition

Memorize **Practice** **Recognize**

animals - snake

Example 3: retrieval-induced inhibition

Memorize **Practice** **Recognize**

`animals - elephant`

Example 3: retrieval-induced inhibition

Memorize **Practice** **Recognize**

vegetables - onion

Example 3: retrieval-induced inhibition

Memorize **Practice** **Recognize**

occupations - teacher

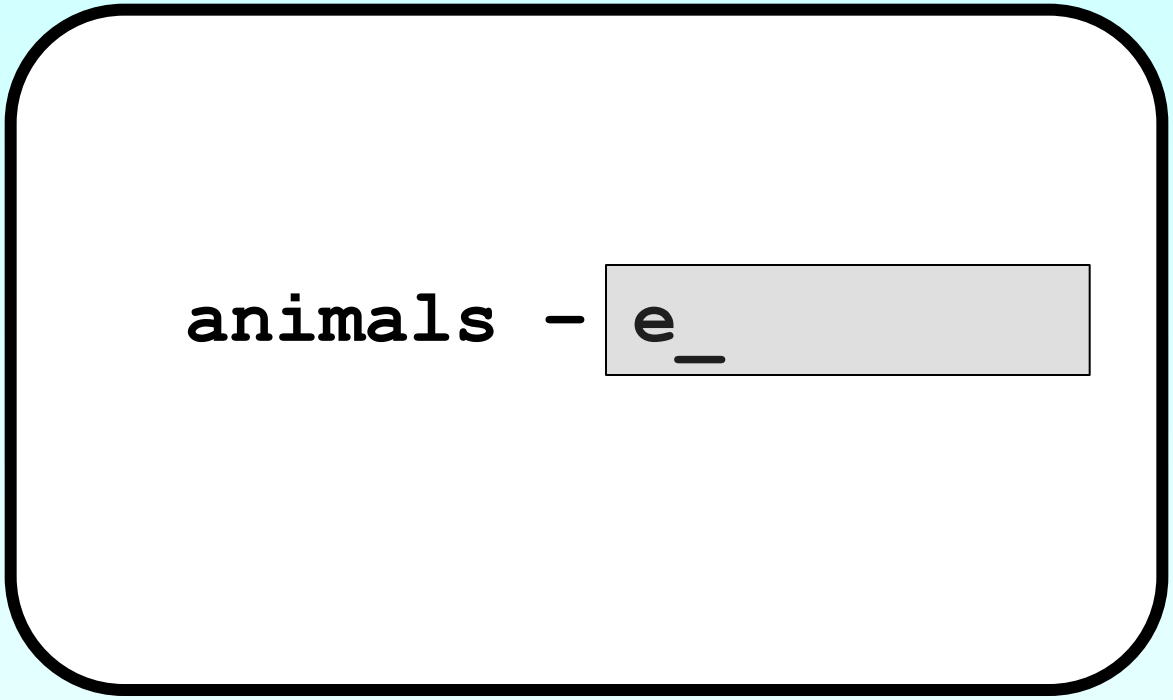
Example 3: retrieval-induced inhibition

Memorize | **Practice** | **Recognize**

animals – s_

Example 3: retrieval-induced inhibition

Memorize | **Practice** | **Recognize**



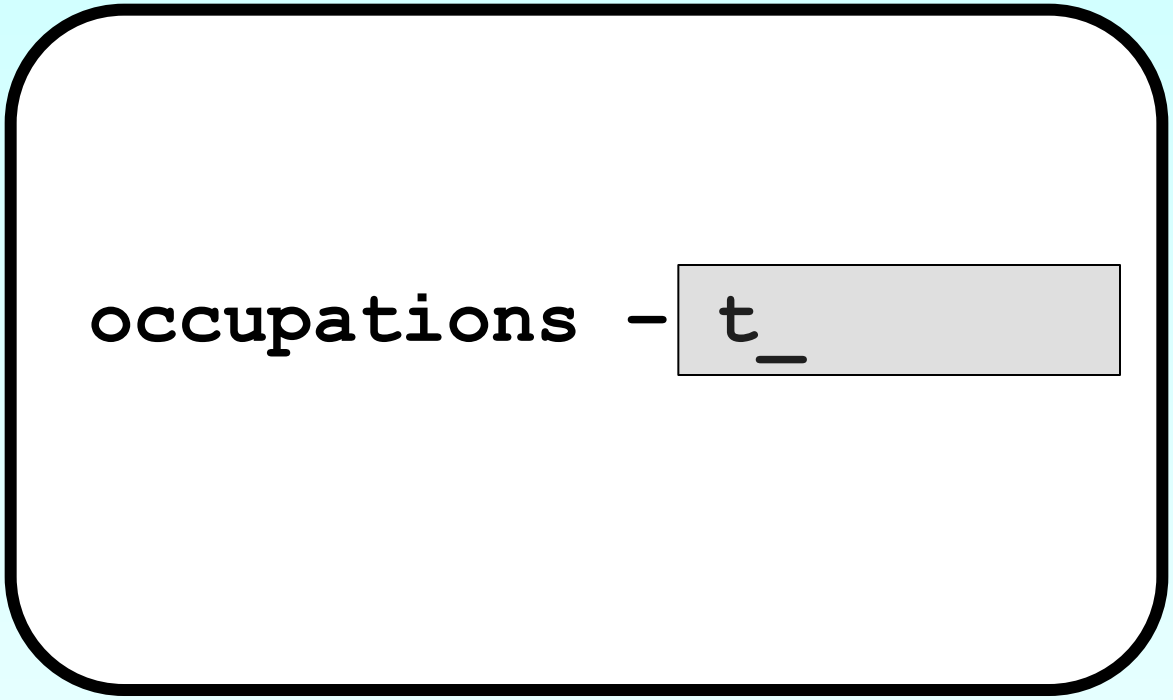
Example 3: retrieval-induced inhibition

Memorize | **Practice** | **Recognize**

vegetables – o_

Example 3: retrieval-induced inhibition

Memorize | **Practice** | **Recognize**



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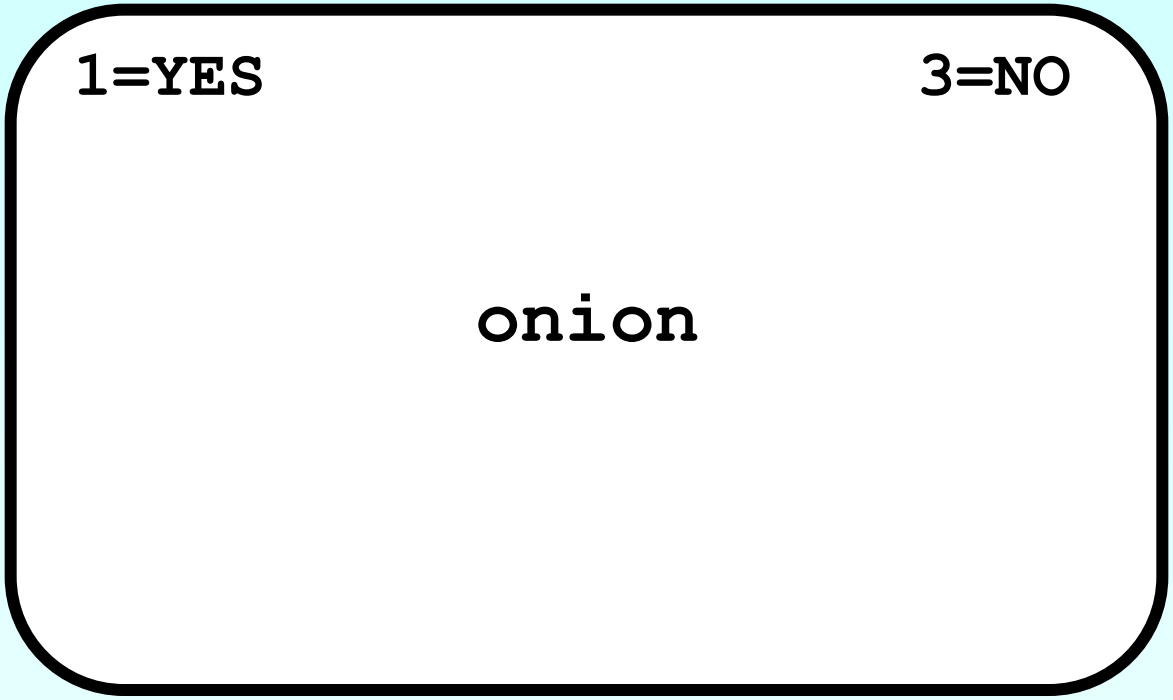

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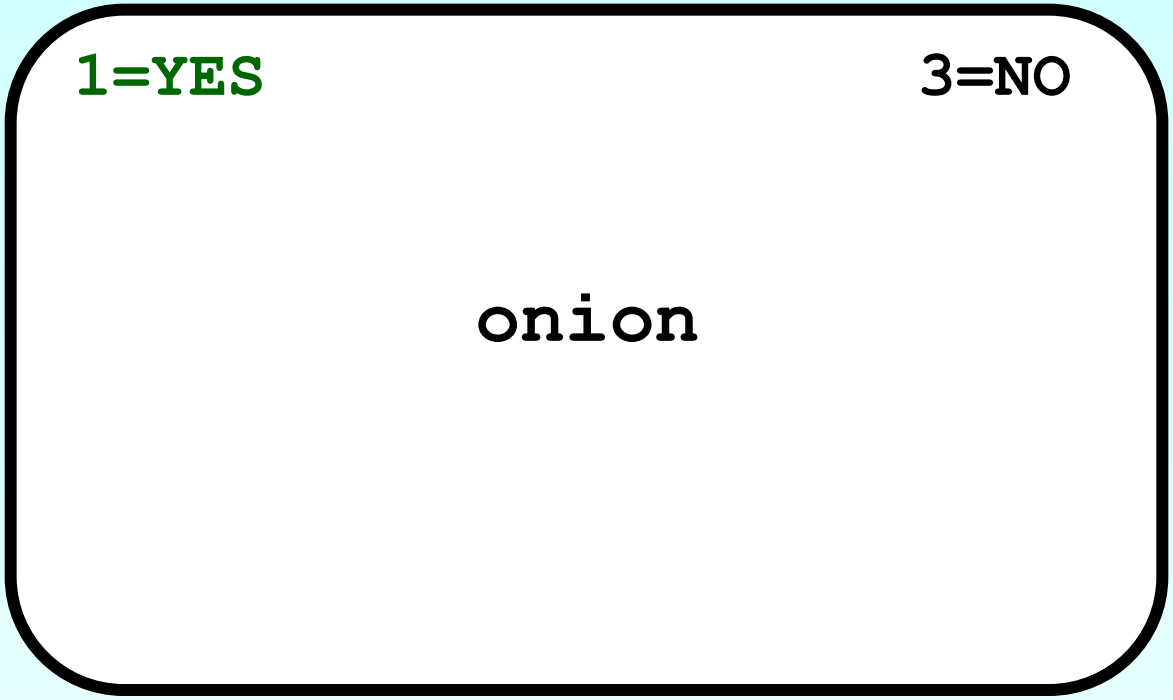

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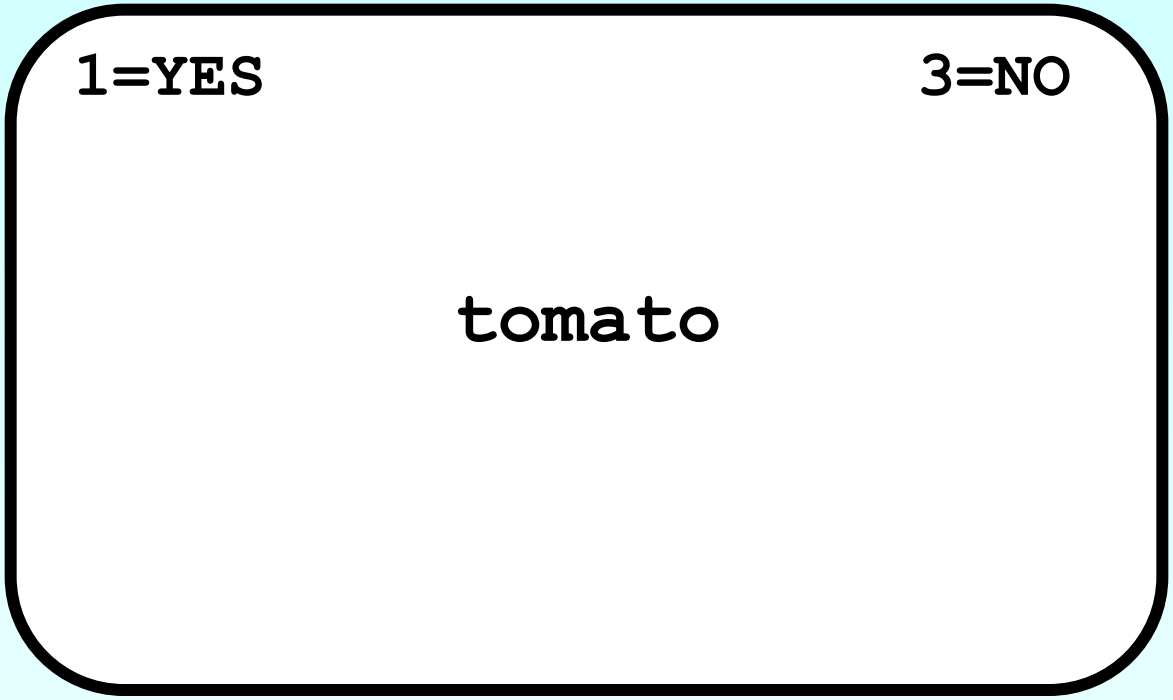

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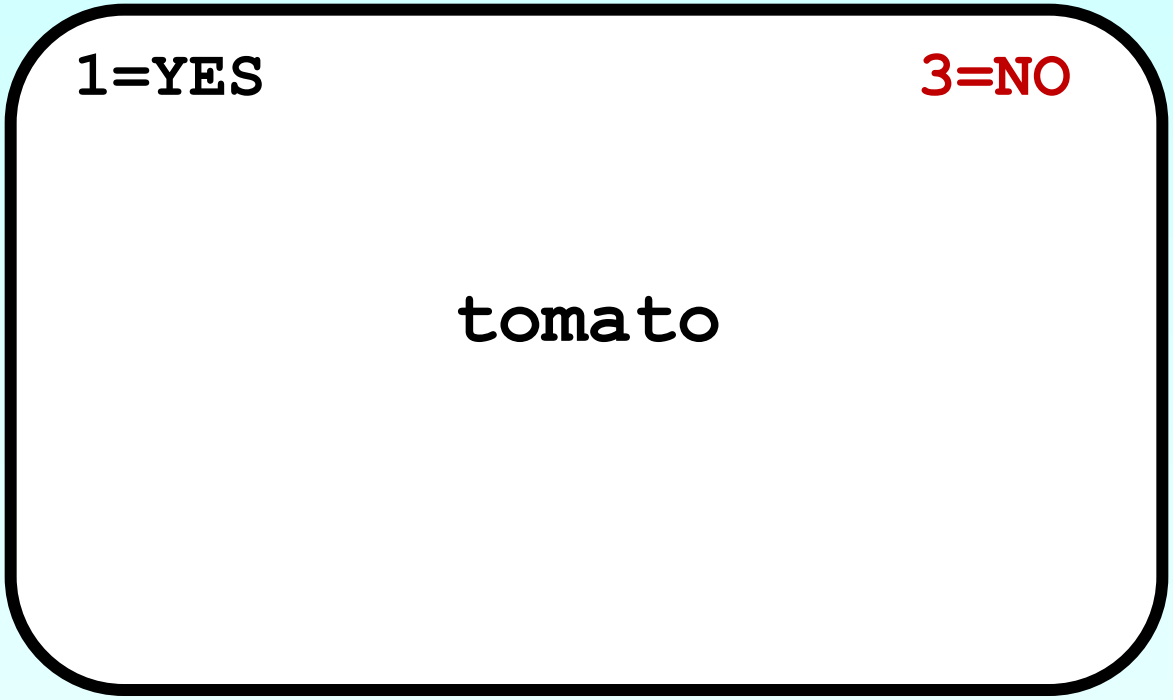

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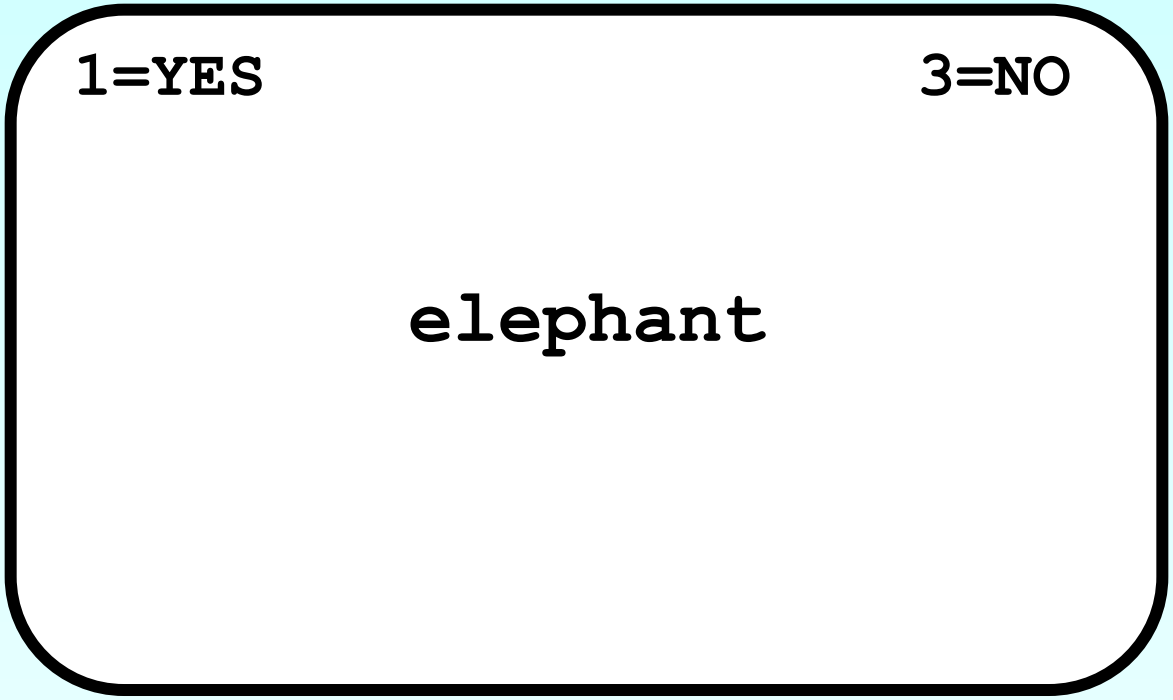

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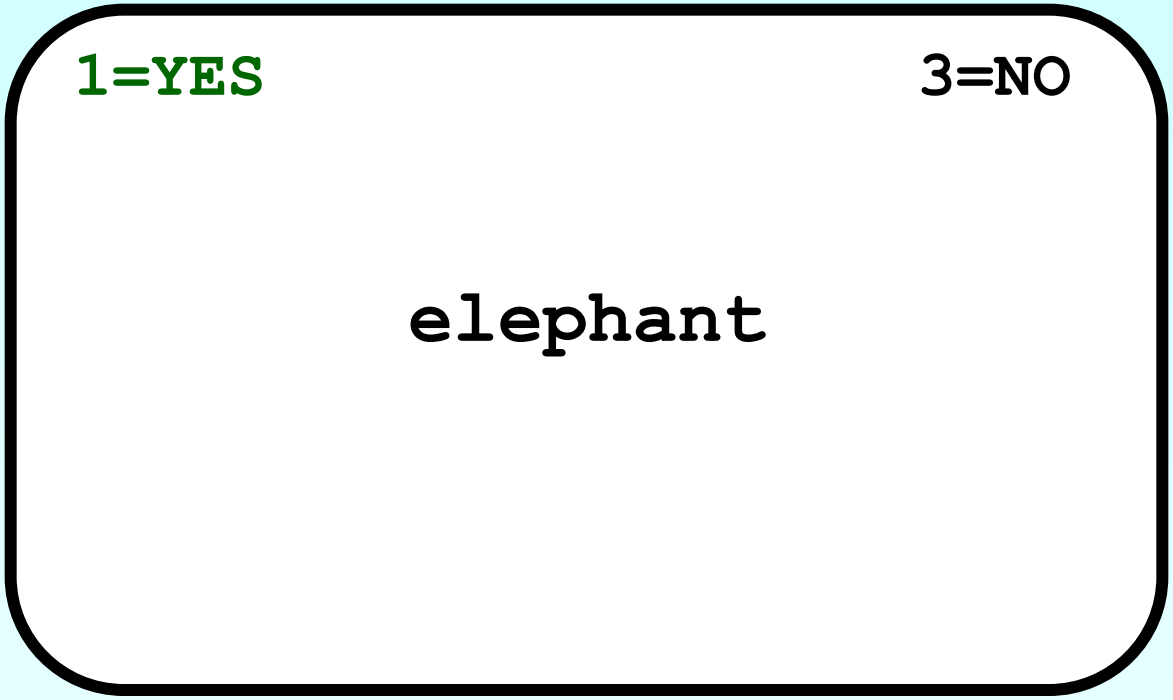
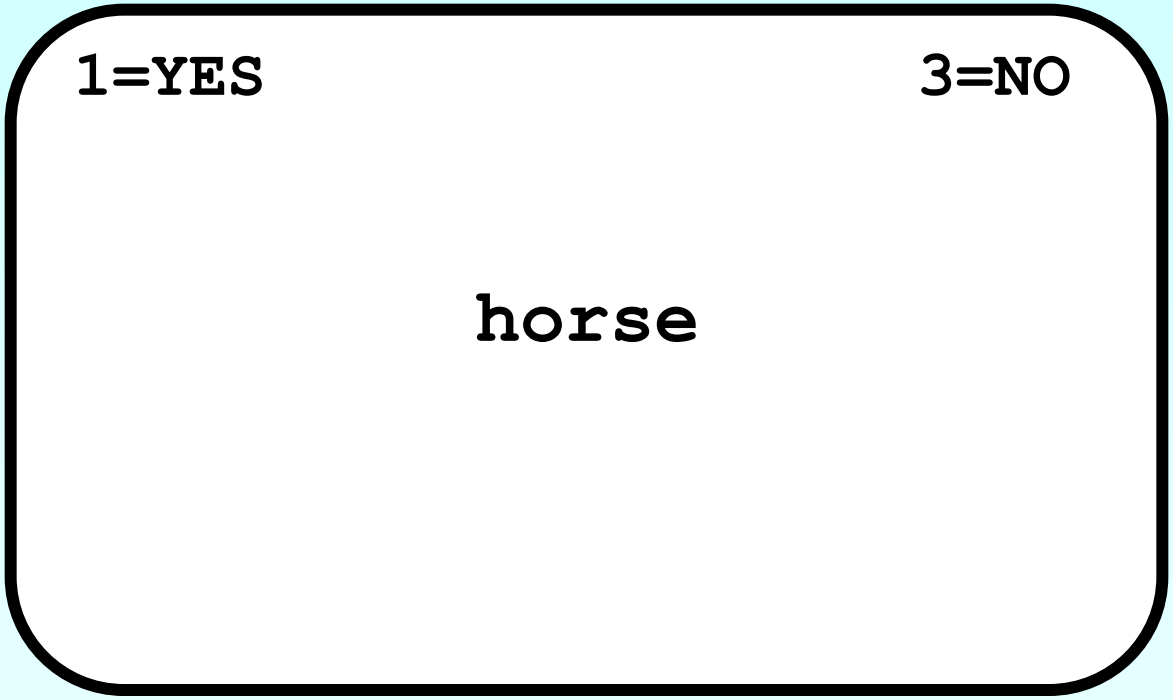


Example 3: retrieval-induced inhibition

Memorize | **Practice** | **Recognize**



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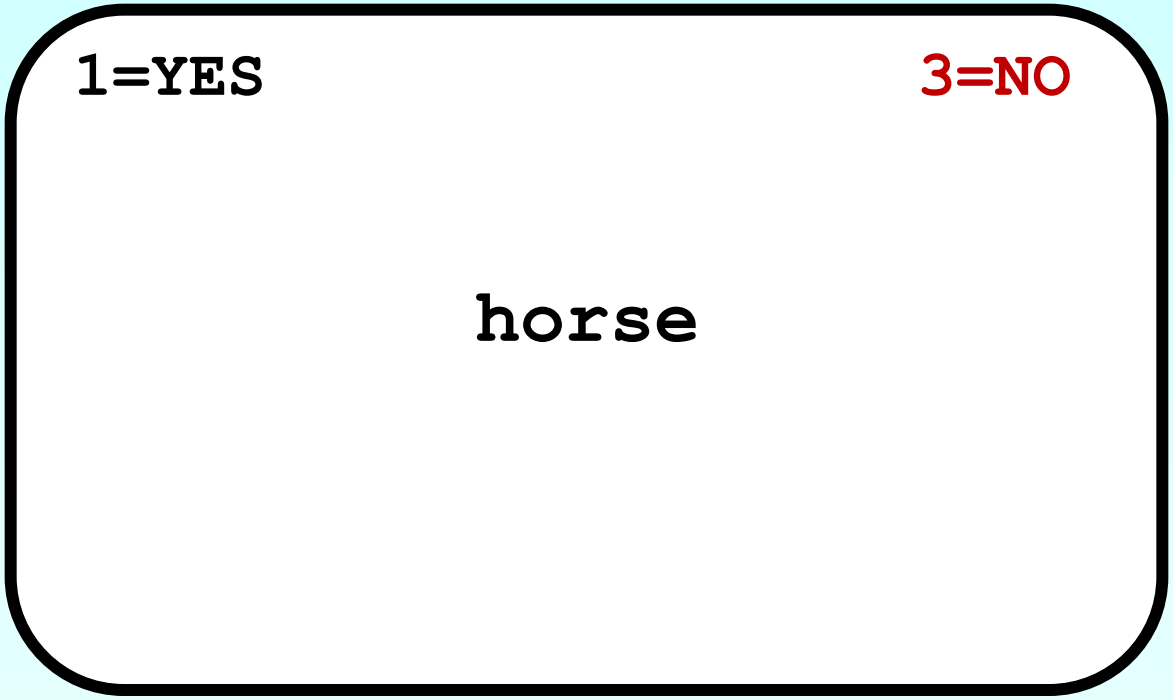

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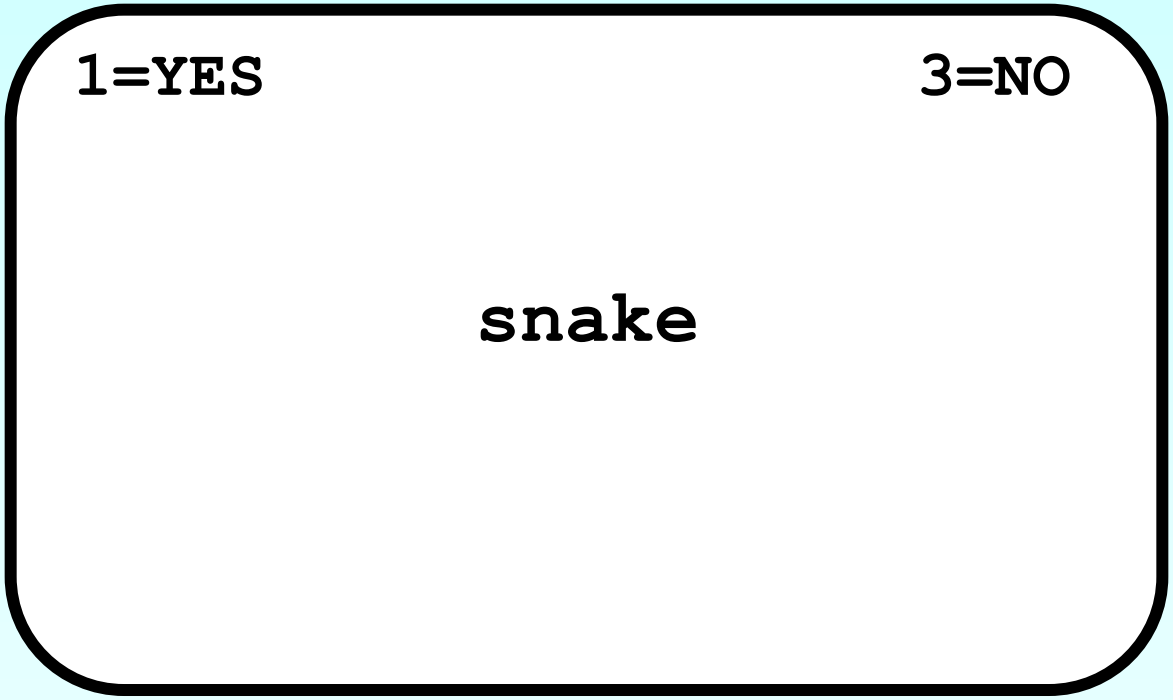

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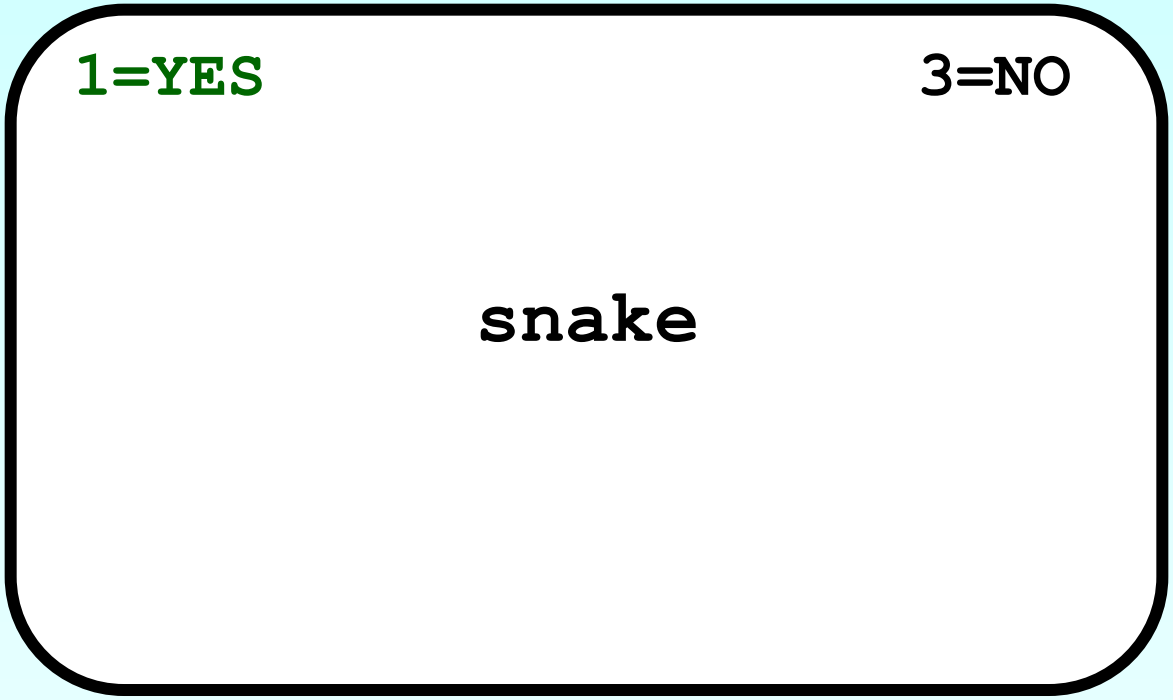

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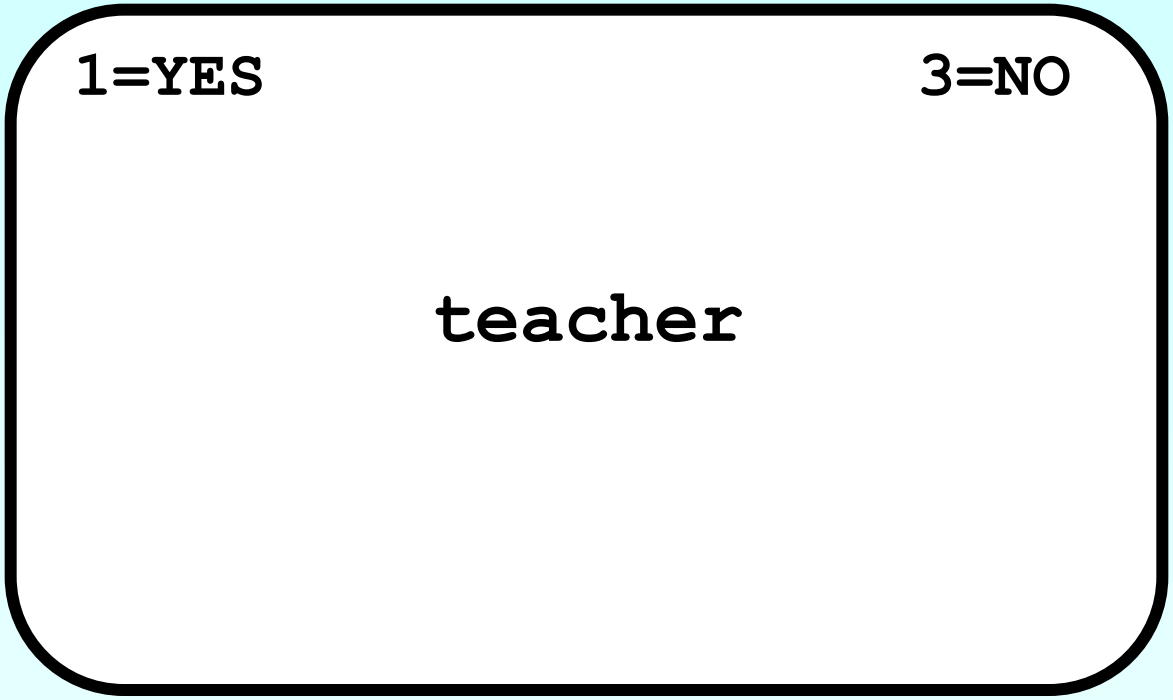

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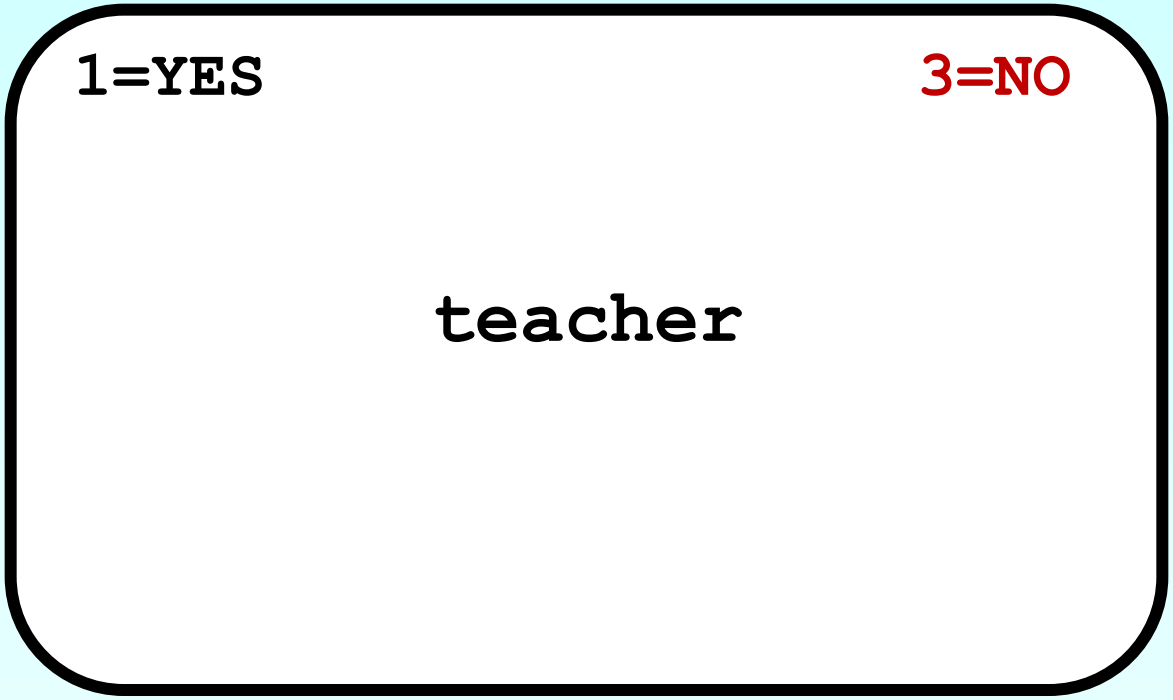
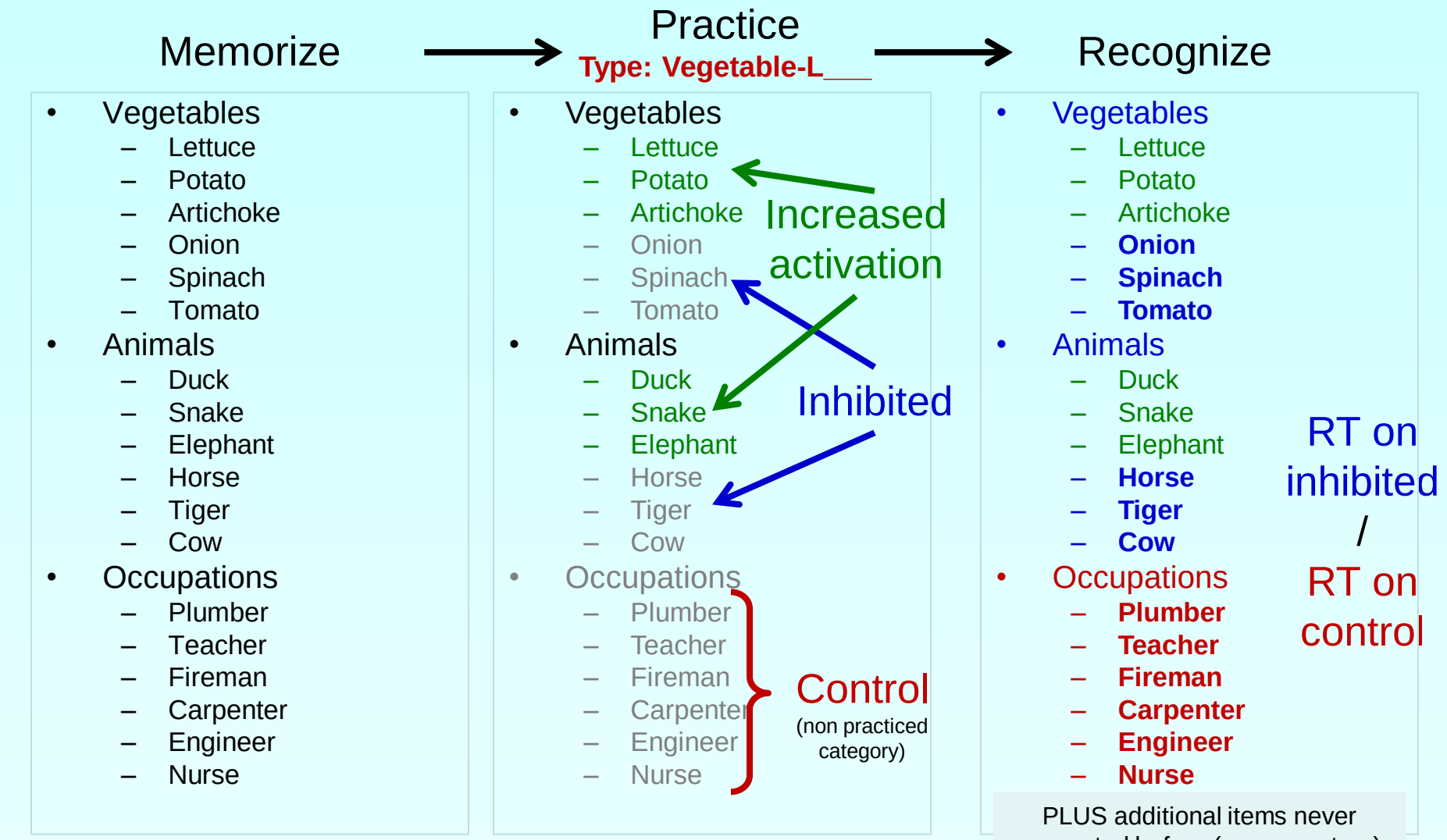
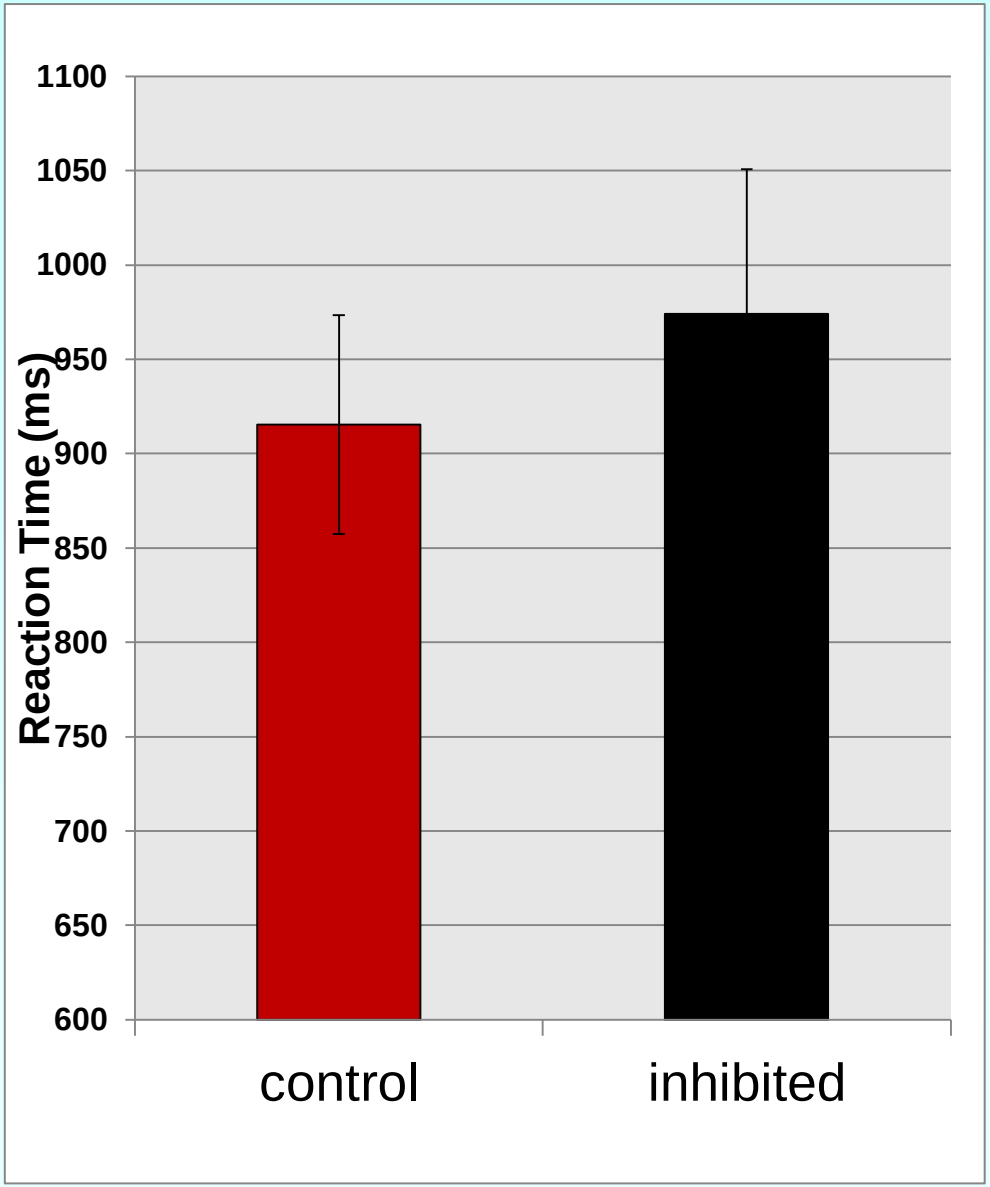


Example 3: retrieval-induced inhibition



Inhibition score =
(RT to inhibited)/(RT to control)

Example 3: retrieval-induced inhibition



Background to the present study

Inhibition

Attention control

PSTM

L2 production

L2 perception

- Pure tone hearing test
- Vocabulary size
- Background questionnaire

Spain

35 L2 learners of English
(L1 Spanish Monolinguals)
+ 10 native speakers (control)
Universidad de Sevilla

52 L2 learners of English
(Spanish-Catalan Bilinguals)
Universitat de Barcelona

United States

26 L2 learners of Spanish
(L1 English Monolinguals)
+ 9 native speakers (control)
Indiana University

Darcy, Mora & Daidone (2014)
Mora & Darcy (2013, 2014)

The present study

Spain

52 L2 learners of English
(Spanish-Catalan Bilinguals)
Universitat de Barcelona

- Could understand & speak both Ls
- Used Spanish & Catalan daily
- Differed in **amount of use of less dominant language**.

2 groups:

< 30%	**“unbalanced”**
> 30%	**“balanced”**

35 L2 learners of English
(L1 Spanish Monolinguals)

26 L2 learners of Spanish
(L1 English Monolinguals)

Unbalanced bilinguals need to strongly inhibit their more proficient language when using their less dominant one (≠ “balanced” bilinguals).

> enhanced inhibitory skill

> more efficient L1 inhibition when using L2 English

Tasks: L2 phonological processing

L2 production

- **Delayed sentence repetition task**
  - **Vowel production**
  - **Consonant production**

L2 perception

- **ABX Categorization**
  - **Vowel contrasts**
  - **Consonant contrasts**

All tasks performed in L2 and L1 by all groups, but we focus on L2-English learners

L2 English contrasts

Darcy, Mora & Daidone (2014)
Mora & Darcy (2013, 2014)

Production: delayed sentence repetition

- 4 pairs of sentences for each contrast (total: 16 per language)
- L2 learners + NS controls

Spanish L2:
Bloomington
(L1-En monolinguals)

/el - /eɪ /

- *¿Qué ruido ha sido ese?* Es la **maceta** que se ha roto.
- *¿Qué le pones a la ensalada?* Un buen **aceite** de oliva.

/r/ - /ð/

- *Parece que tienes frío!* Tengo la **cara** helada del frío.
- *No nos ha contado esta historia antes?* Cuenta **cada** historia mil veces.

English L2:
Sevilla (L1-Sp monolinguals)
Barcelona (Sp/Cat bilinguals)

/i:/ - /ɪ/

- *Which one do you like best?* I like the **cheap** one.
- *What would you like with it?* I'll have the **chips** please.

/ʃ/ - /tʃ/

- *Could you buy some wine?* All the **shops** are closed, sorry.
- *Are you not finishing the pork chops?* The **chops** are too much, I'm full.

Production: delayed sentence repetition

- 4 pairs of sentences for each contrast (total: 16 per language)
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Spanish L2:
Bloomington
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Production measures

- 4 pairs of sentences for each contrast (total: 16 per language)
- L2 learners + NS controls

Spanish L2

/e/ - /eɪ /

- 3 measurement points (MP) within vowels: F1, F2, F3, F0
- **Amount of tongue movement** (Bark difference score) from MP2 to MP1

/ɾ/ - /ð/

- Visual and auditory examination of spectrogram
- Categorical decision about tap vs. spirantized /ð/
- Score out of 8

English L2

/i:/ - /ɪ/

- 3 measurement points (MP) within vowels: F1, F2, F3, F0
- **Spectral distances** (Bark) at midpoint and Euclidean distances

/ʃ/ - /tʃ/

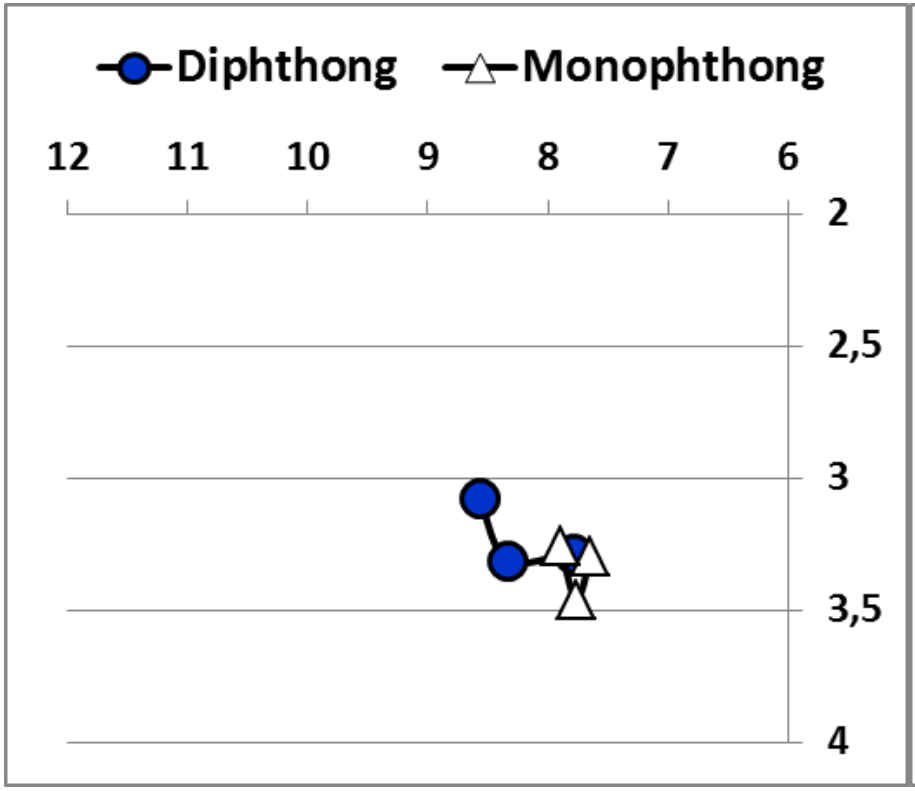
- Visual and auditory examination of spectrogram
- Categorical decision about presence vs. absence of closure
- Score out of 8

Darcy, Mora & Daidone (2014)
Mora & Darcy (2013, 2014)

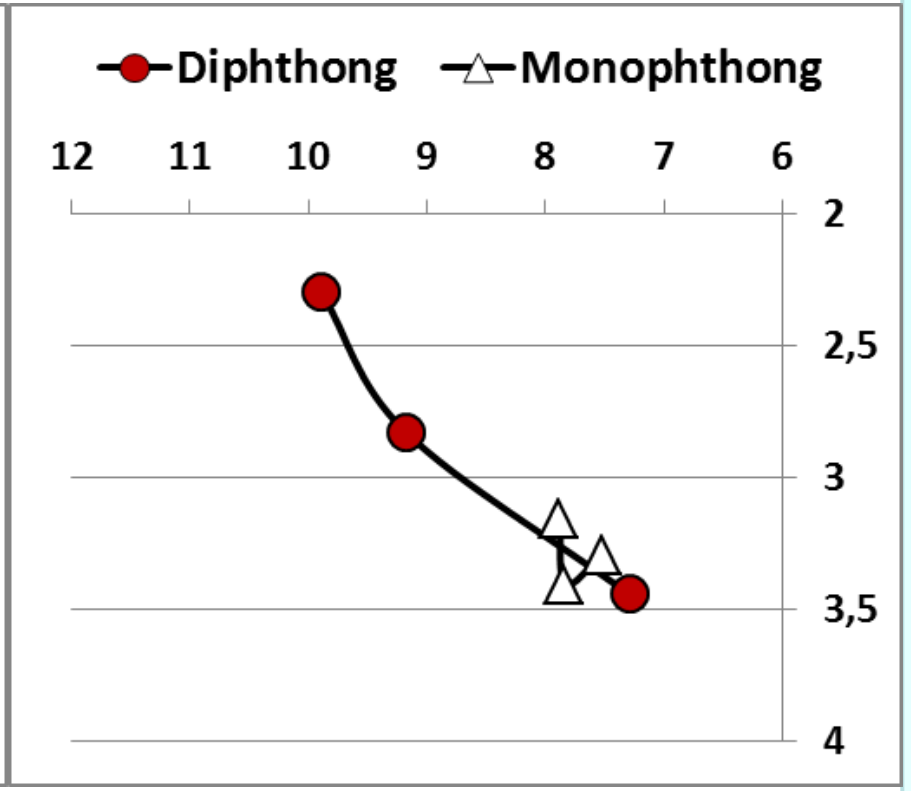
Production results

/e/ - /eɪ / amount of tongue movement

L2 Spanish



L1 Spanish

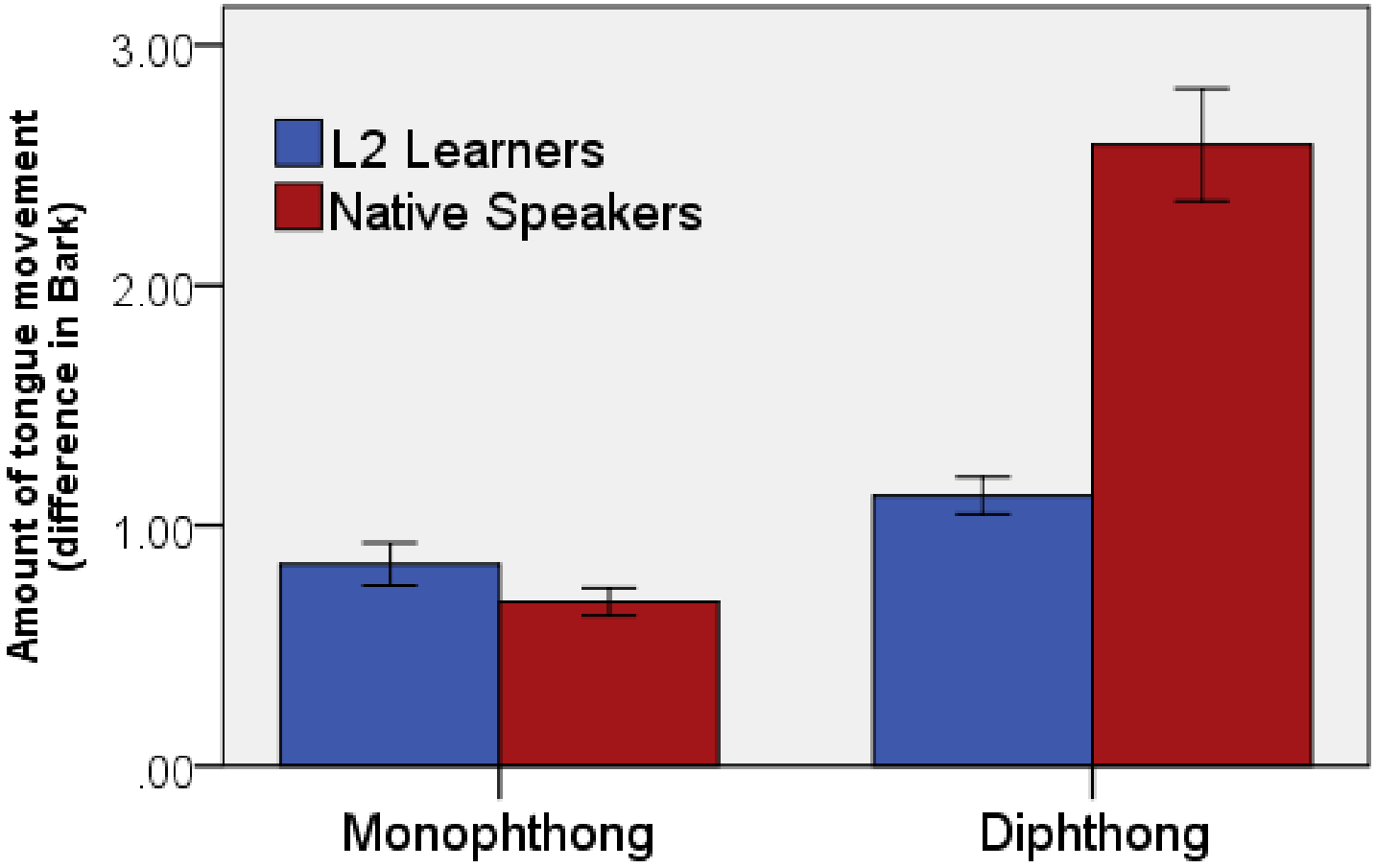


Darcy, Mora & Daidone (2014)
Mora & Darcy (2013, 2014)

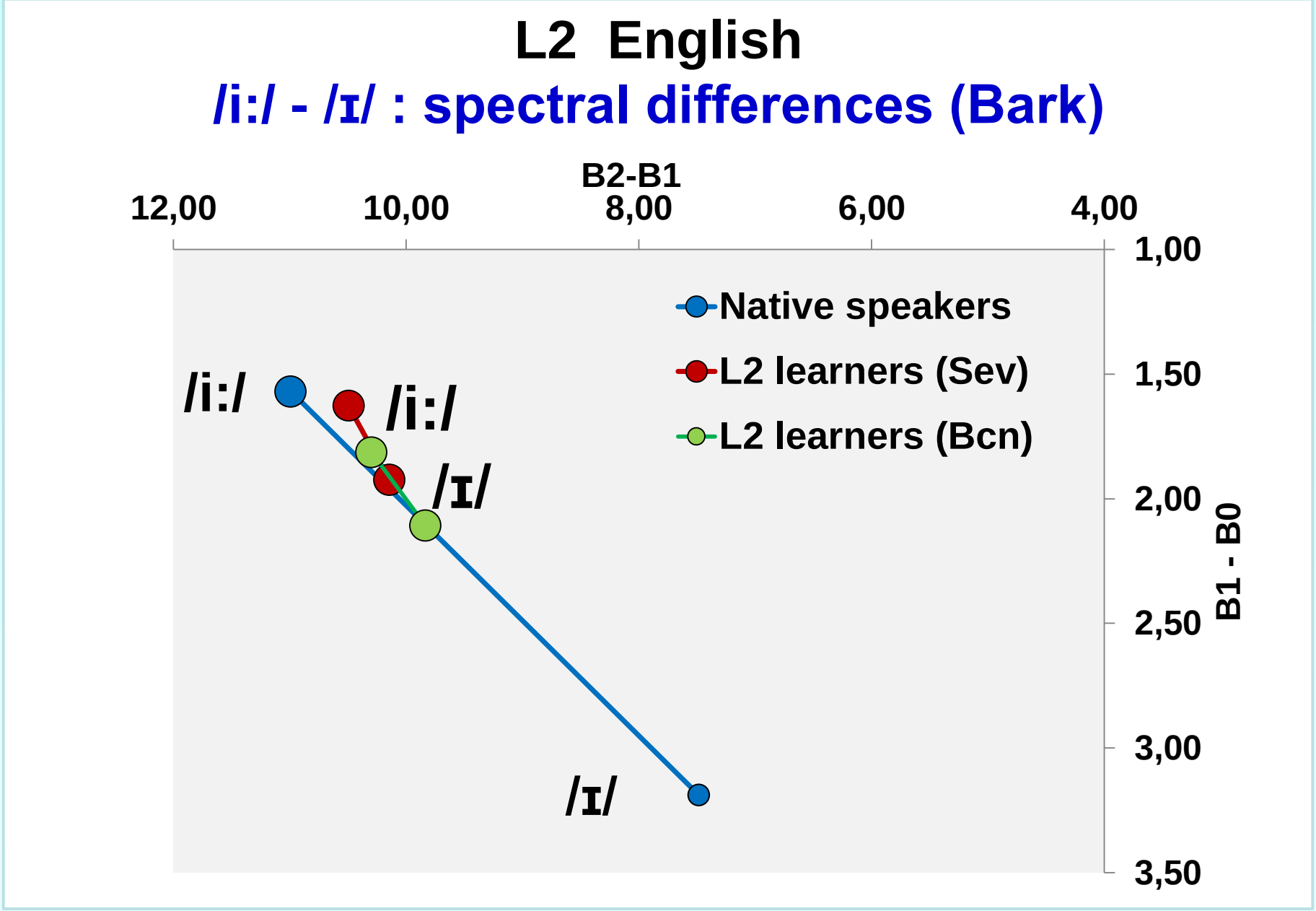
Production results

L2 Spanish

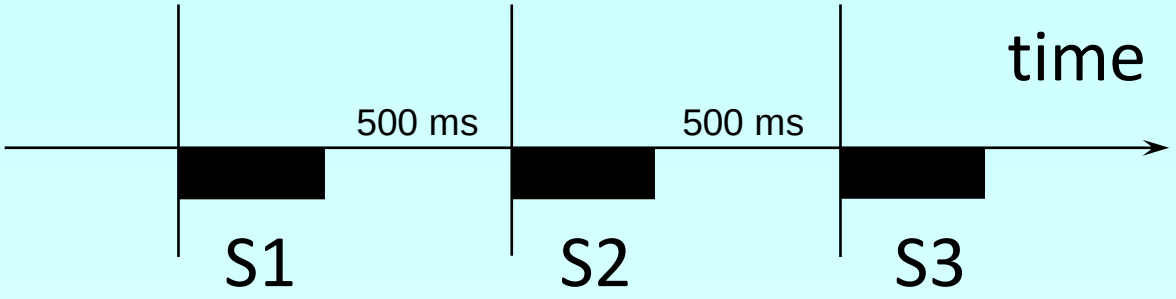
/e/ - /eɪ /: amount of tongue movement



Production results



Perception task: speeded categorical ABX task



A A — B B — **A B** → *Response: A or B*

female voice 1 — *female voice 2*

- Stimuli in Spanish and English (non-words)
- Stimuli recorded by two female early balanced bilinguals (Mexican Spanish / American English)
- All subjects heard all stimuli
- Language switch between 2 blocks
- 4 orderings: ABA, ABB, BAA, BAB = 128 trials

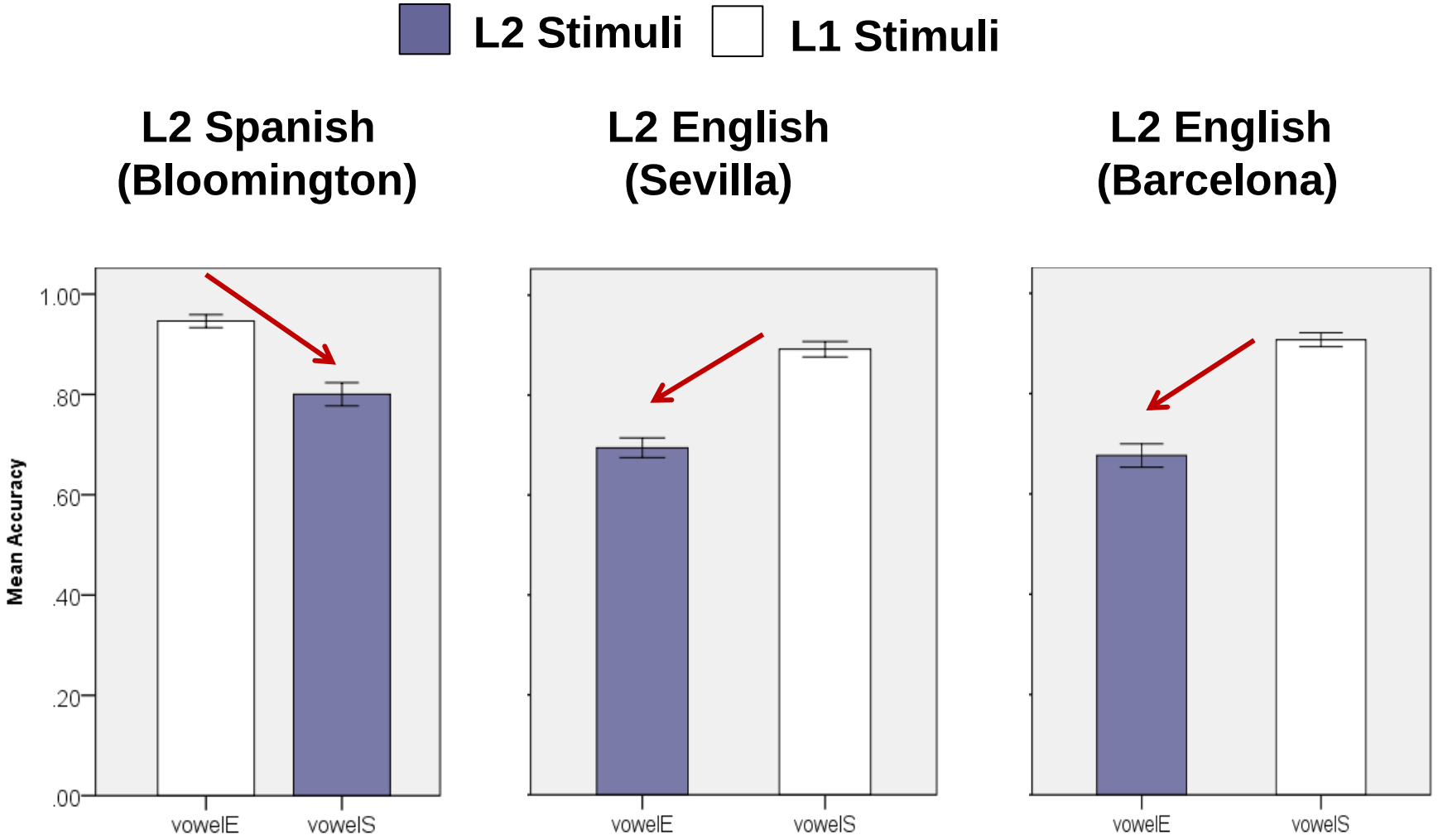
Perception: speeded categorical ABX discrimination

Sample of trisyllabic nonword stimuli in Spanish and English
[4 items per condition]

Stimulus language	item A	item B	Condition
Spanish	saˈɾeβo	saˈðeβo	Test C
English	səˈʃi:dən	səˈʧi:dən	Test C
Spanish	faˈneða	faˈneɪða	Test V
English	fəˈni:dɪʃ	fəˈnɪdɪʃ	Test V
Spanish	gaˈtaso	gaˈðaso	Control C
English	gəˈtæfɪn	gəˈdæfɪn	Control C
Spanish	luˈpito	luˈpato	Control V
English	ləˈpi:dɪk	ləˈpædɪk	Control V

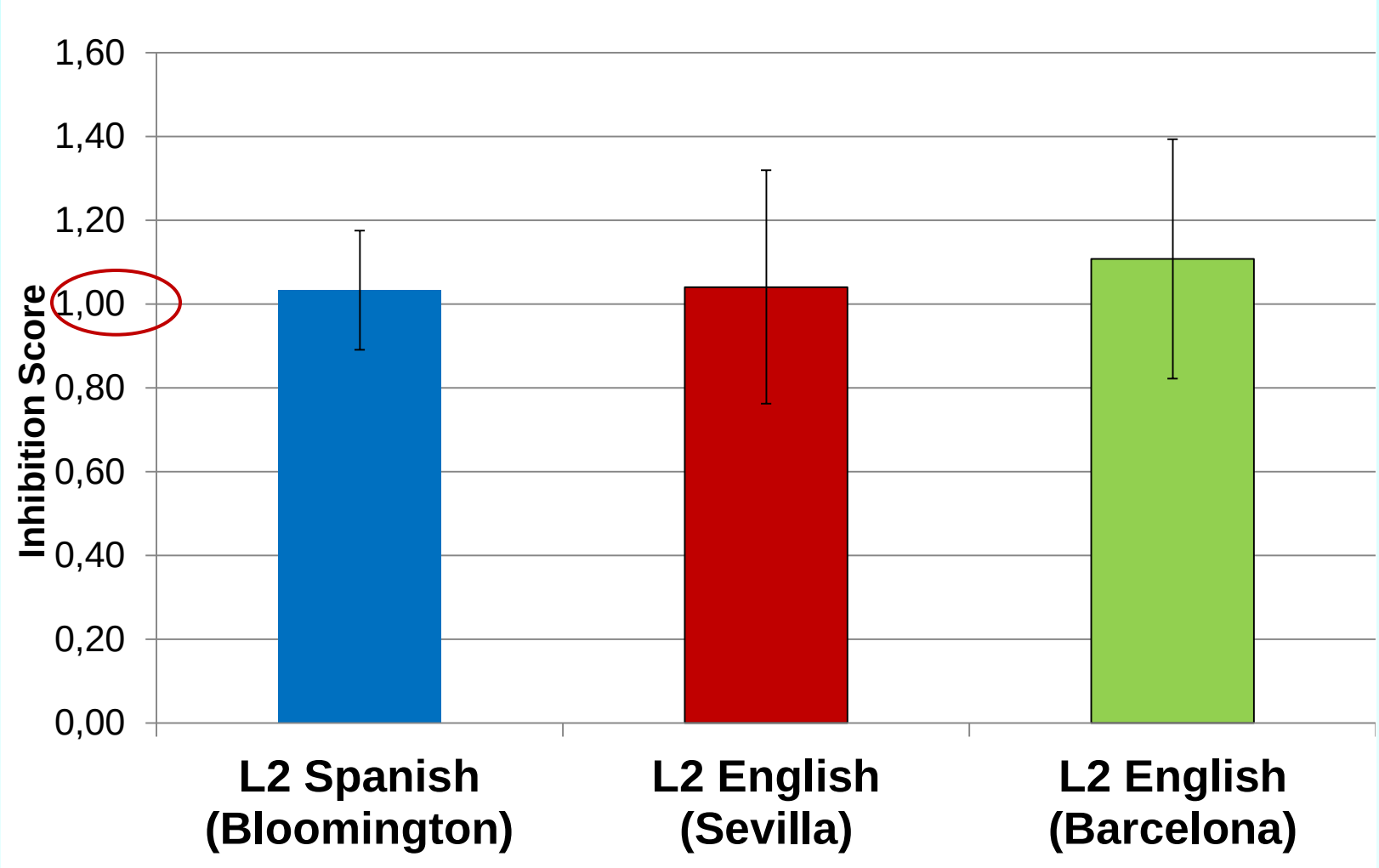
Darcy, Mora & Daidone (2014)
Mora & Darcy (2013, 2014)

Perception results (test conditions)



Darcy, Mora & Daidone (2014)
Mora & Darcy (2013, 2014)

Inhibition: group results



Error bar = 1 SD

Darcy, Mora & Daidone (2014)
Mora & Darcy (2013, 2014)

Inhibition: monolingual L2 learners

(Proficiency partialled out)

- Inhibition

- ABX accuracy

	Perception (ABX)
Inhibition (score)	L2 Sp (Monolingual-Bloomington) ***r*= .507*** L2 En (Monolingual-Sevilla) ***r*= .615***

Darcy, Mora & Daidone (2014)
Mora & Darcy (2013, 2014)

Inhibition: results

(Proficiency partialled out)

- Inhibition

- ABX accuracy

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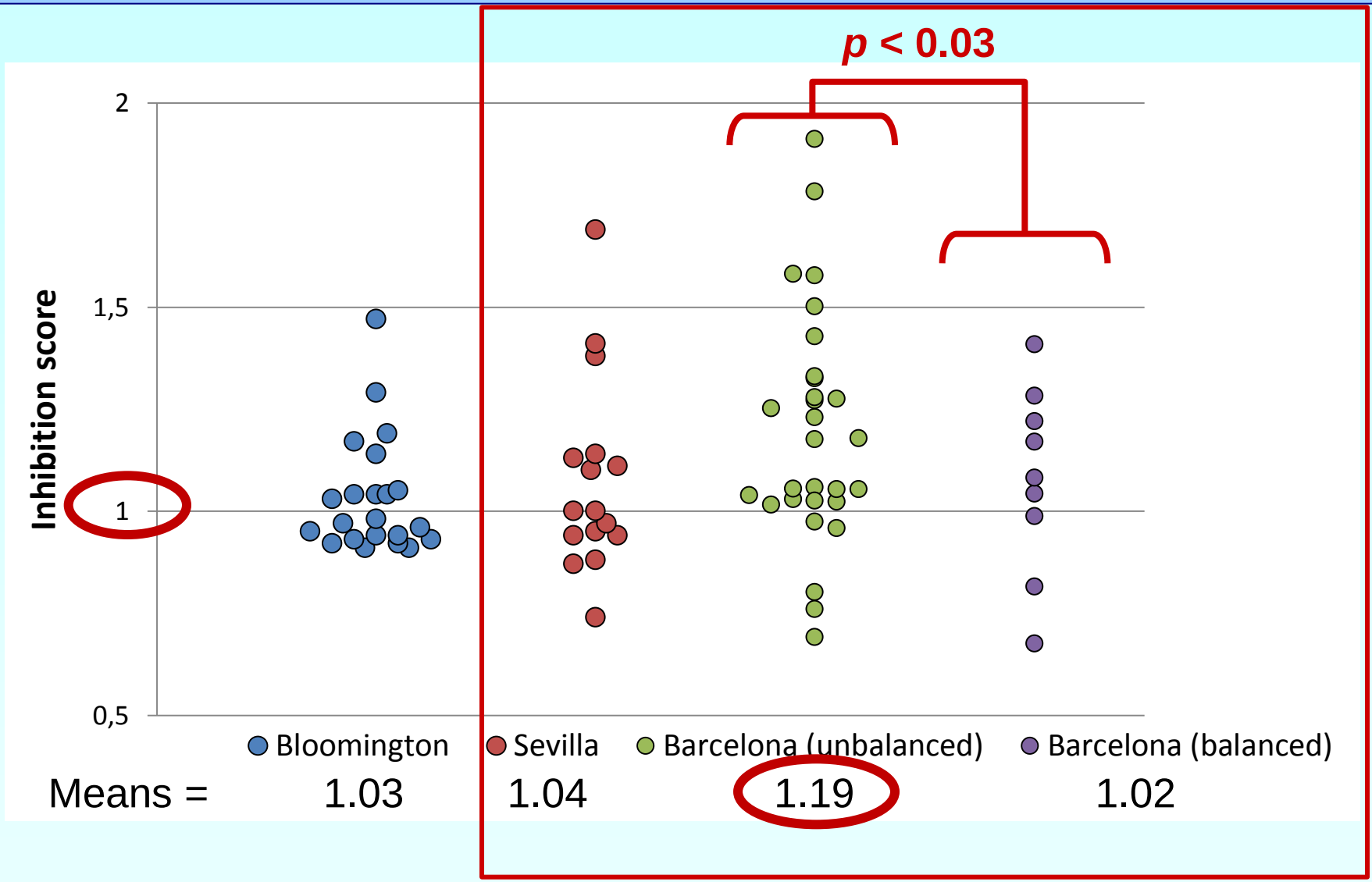
Inhibition (score)	L2 Sp (Monolingual-Bloomington) ***r*= .507*** L2 En (Monolingual-Sevilla) ***r*= .615*** **L2 En (Bilinguals-Barcelona)?**

Darcy, Mora & Daidone (2014)
Mora & Darcy (2013, 2014)

Inhibition: Individual Results



Darcy, Mora & Daidone (2014)
Mora & Darcy (2013, 2014)

Findings

Inhibition score ⟷ **- Perception (ABX)**
- Production accuracy

	Perception (ABX)	Production (Cs)	Production (Vs)
L2 Sp	r = .507*	r =.324	r =-.216
L2 En (Sev)	r = .615*	r =.169	r =.024
L2 En (Bcn)	r =.012	n.A.	r =-.062

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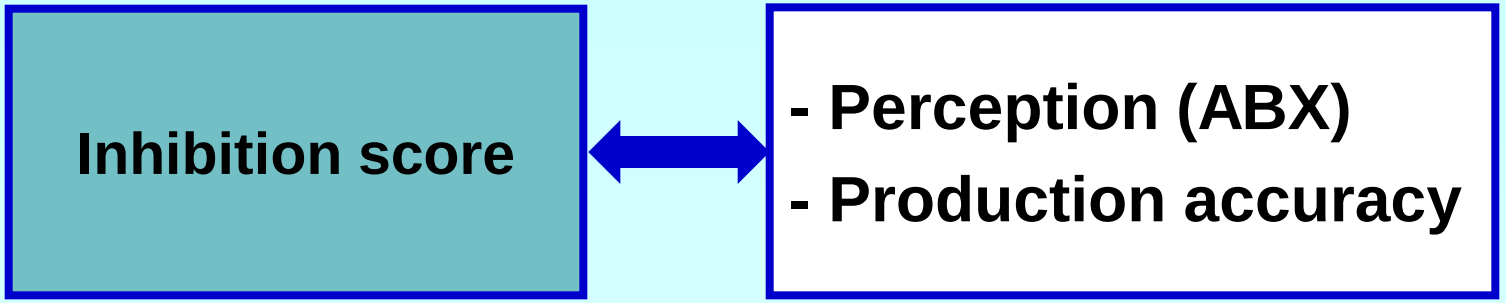

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balanced (> 30%)	r=.160	n.A.	r= -.327
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Discussion and Conclusions

Monolingual Context:

- Inhibition was related to L2 perception, but not L2 production.

Bilingual Context:

- Inhibition was unrelated to L2 perception or production

- This appeared to be the case for "balanced" as well as "unbalanced" bilinguals.

Darcy, Mora & Daidone (2014)
Mora & Darcy (2013, 2014)

Discussion and Conclusions

Why did we fail to find a relationship between Inhibition and perception and production for Barcelona bilinguals?

- Perhaps the effects of individual differences in inhibitory skill are "washed out" in bilinguals due to the daily practice they receive in inhibiting one language over the other (irrespective of how balanced they are).

Darcy, Mora & Daidone (2014)
Mora & Darcy (2013, 2014)

Further research

Contexts of language use where Individual Differences in inhibitory control can be investigated further:

- **L2 effects on L1 in L2-immersion.** Lev-Ari & Peperkamp (2013)
- **Modulation of cognate effects**
- **L1 transfer at various levels of L2 phonological processing.**
- **L2 speech learning by Monolinguals vs. Bilinguals.**
- **Developing new (speech-based) tasks**

Darcy, Mora & Daidone (2014)
Mora & Darcy (2013, 2014)

Merci!

Thank you!