Individual differences in cognitive ability and L2 speech perception

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Why study individual differences in L2 phonology?

Acquisition of phonology

Pedagogy:
Pronunciation often is a difficult skill and a **learning challenge** for L2 learners, most learners struggle with pronunciation at most levels of L2 competence.

Research:
Learners vary greatly in the amount of foreign accent they exhibit when speaking an L2. We still don't fully understand the **causes of this inter-learner variation**.

Social dimension:
There is an important social dimension to speaking an L2 with a strong foreign accent: integration, self-confidence, …

> help L2 learners with pronunciation

Factors affecting L2 phonological development

Contextual factors:

Age- and experience-related factors

- L1 background
- Age of Onset of L2 learning
- L2 exposure (Length of Residence)
- Frequency/amount of L1/L2 use

→ Immigrant populations living in L2 community

(Baker et al., 2008; Baker and Trofimovich, 2005; Flege 2009; Flege, Bohn, & Jang, 1997, Flege, Yeni-Komshian, & Liu, 1999; Guion et al., 2000; Moyer 2009; among others)

→ **The earlier the start the better for L2 phonology**

→ **quality and quantity of L2 input received**

Factors affecting L2 phonological development

Contextual factors:

- Formal learning context:
  - > Classroom instruction
  - > Short-term immersion /study abroad

→ Student populations in Foreign Language

(Avello, 2013; Avello, Mora & Pérez-Vidal, 2012; Bongaerts, van Summeren, Planken, & Schils, 1997; Cebrian, 2006; Díaz-Campos, 2004; Fullana, 2006; García-Lecumberri & Gallardo, 2003; Højen 2003; Mora, 2008; Muñoz & Llanes, in press; Piske, 2007; among others)

→ **Very limited gains in L2 phonology**

> Phonetic training in the lab (esp. high variability)

→ Adult learners in L1 & L2 contexts

(Bradlow et al. 1999; Hazan et al., 2005; Iverson and Evans 2009; Logan et al. 1991; Ylinen et al. 2010; among others)

→ **Robust gains in L2 speech perception and production**

Factors affecting L2 phonological development

Very large inter-subject variation even in the LAB context where INPUT and EXPOSURE factors are tightly controlled in the experimental design.

Bradlow, Akahane-Yamada, Pisoni & Tohkura, 1997; Golestani & Zatorre, 2009; Hazan & Kim, 2012; Kim & Hazan, 2010; MacKay, Meador & Flege, 2001; Pallier, Bosch & Sebastián-Gallés, 1997; Polka, 1991)

Individual factors:

- **Motivation**
- **Personality (extroversion, introversion)**
- **Musicality (singing and musical ability)**
- **Sound processing skills (auditory acuity, frequency discrimination)**
- **Imitation skills (aptitude for oral mimicry)**
- **Cognitive skills (working memory, attention, inhibition)**
- **…..**

(Bongaerts et al., 1997; Christiner & Reiterer, in press; Hazan & Kim, 2012; Kim & Hazan, 2010; Lengeris & Hazan, 2010; Moyer, 1999; Gottfried, 2007; Slevk and Miyake, 2006; Reiterer et al. 2011; Hu et al. 2013)

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Factors affecting L2 phonological development

Cognitive factors:

- Working memory (WM)
- Phonological short-term memory (PM)
- Acoustic memory (AM)
- Attention Control (AC)
- Inhibition (INH)
- …

(Cerviño-Povedano & Mora, 2011; Darcy et al. 2011; submitted; Lev-Ari & Peperkamp, 2013; MacKay et al., 2001; Masoura & Gathercole, 1999; Papagno & Vallar, 1995; Safronova & Mora, 2013; Segalowitz 1997; Service 1992;)

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To what extent do learners' individual differences in their capacity and use of these skills relate to their L2 phonological development?

(Cerviño-Povedano & Mora, 2011; Darcy et al. 2011; submitted; Lev-Ari & Peperkamp, 2013; MacKay et al., 2001; Masoura & Gathercole, 1999; Papagno & Vallar, 1995; Safronova & Mora, 2013; Segalowitz 1997; Service 1992;)

Cognitive skills and L2 speech perception

Cognitive ability → **L2 phonological acquisition**

Phonological short-term Memory (PM)

Acoustic Memory (AM)

Attention Control (AC)

INHIBITION (INH)

- Phonetic training
- Cross-language speech perception
- Training cognitive skills
- L2 phonological development

Cognitive skills and L2 speech perception

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Speech-based tasks

Categorization tasks:

- Forced choice identification
- AXB / ABX Discrimination
- Oddity discrimination

Stimuli:

- L2 words / nonwords
- L2 English (and L2 Spanish)

Advantages of language- or speech-based tasks

- Measures relate more directly to recruitment of cognitive resources required in language processing

  e.g. syntax, semantics, phonology

- Different cognitive skills may be involved in different ways in different domain-specific language functions

  e.g. inhibition in language switching vs. inhibition in lexical access and retrieval

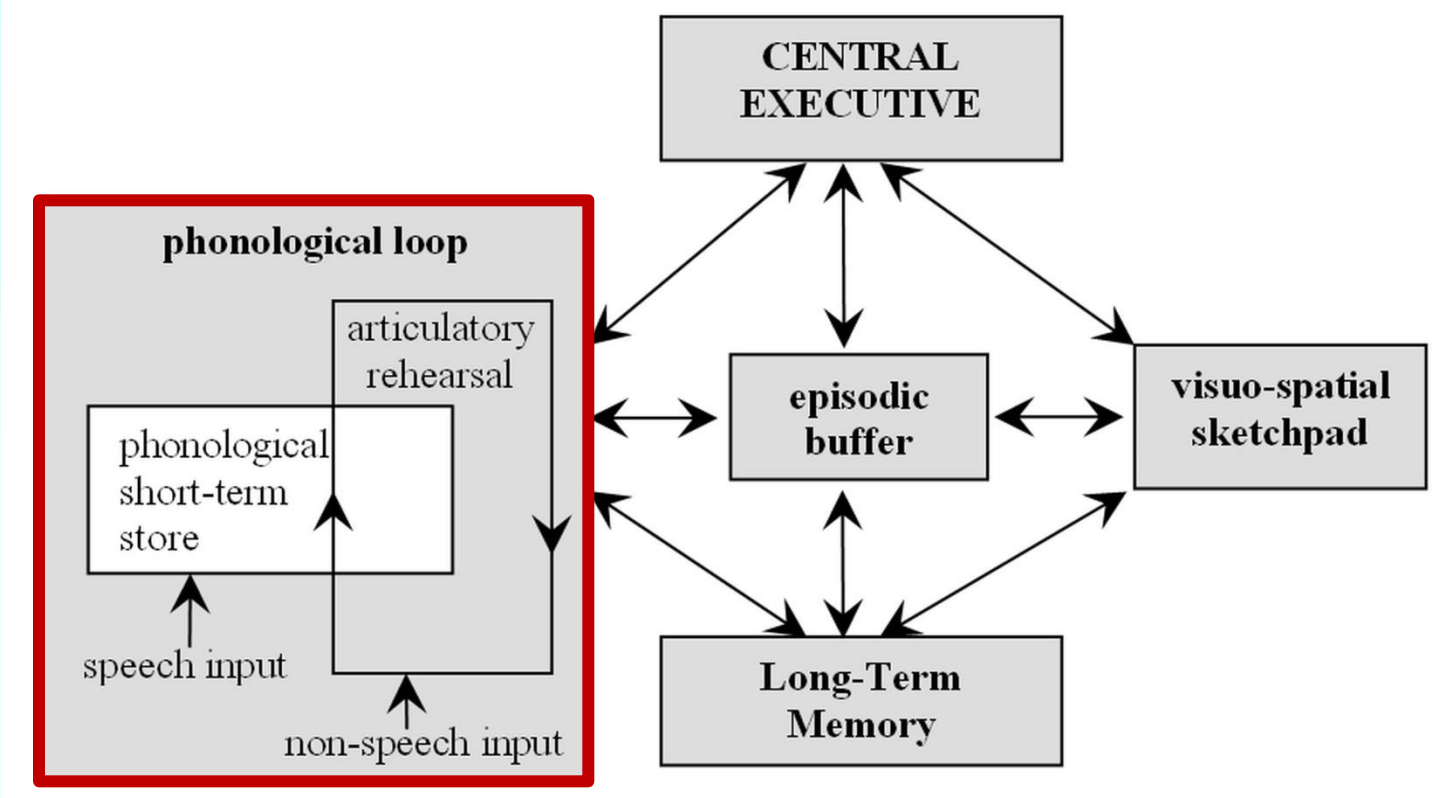
→ BUT - less “universal/pure”?

- biased? > language knowledge

Phonological short-term memory (PM)

Responsible for encoding of phonological elements and their serial order and storing them in LTM.

- **necessary for language processing**
- **Individuals vary in their PM capacity**



(Baddeley and Hitch 1974; Baddeley 1986, 2000, 2003)

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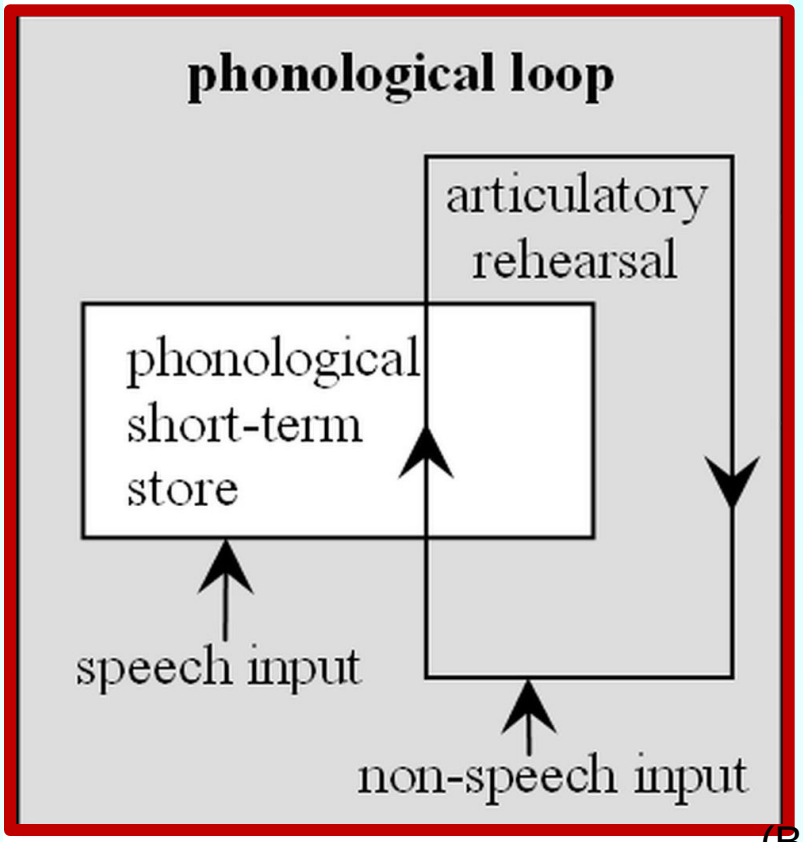


- PM stores auditory-verbal information temporarily

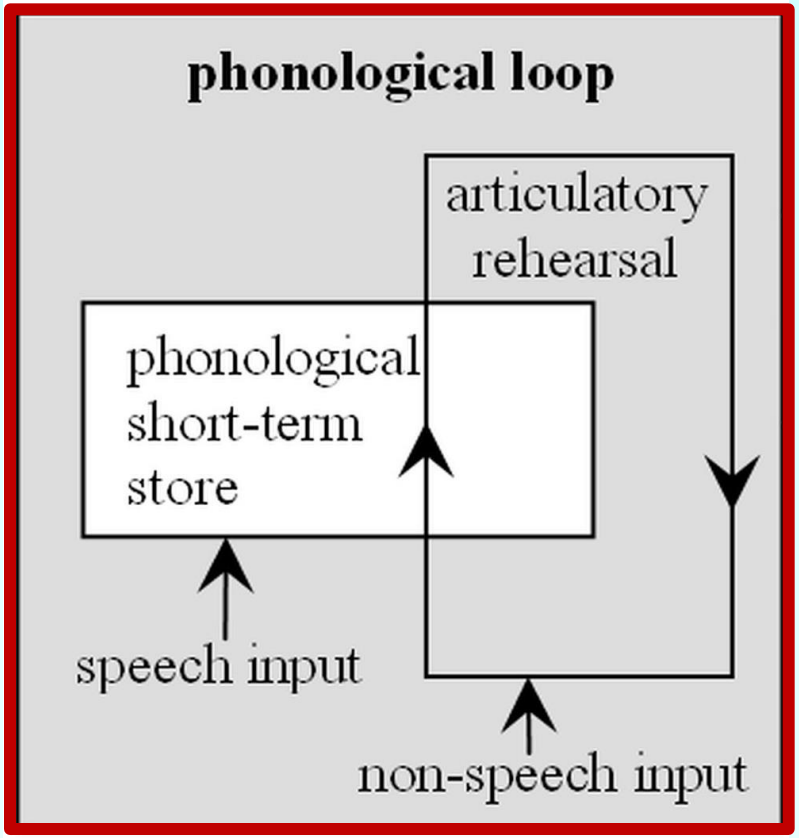
- Decaying auditory traces are refreshed through sub-vocal articulatory rehearsal mechanism

- Capacity: few secs. / 7 auditory representations

(Baddeley and Hitch 1974; Baddeley 1986, 2000, 2003)

Phonological short-term memory (PM)

Learners with larger PM capacity may be more efficient in the processing of L2 sounds:



- **Speech segmentation.**
- **Phonological and lexical encoding.**
- **Cross-language speech perception: L1-L2 sound differences.**
- **Perception of acoustic differences between contrasting L2 sounds.**

(Adams *et al.*, 1999; Adams and Gathercole 1996, 2000; Atkin & Baddeley, 1998; Baddeley, 1993; Blake *et al.*, 1994; Dufva and Voeten 1999; Gathercole, et al. 1997, 1999; French, 2006; French and O'Brien, 2008; Mackay, et al.,2001; O'Brien *et al.,* 2006, 2007)

Phonological short-term memory (PM)

Serial nonword recognition (SNWR)

Identifying pairs of nonword sequences (in L1) of increasing length as Same/Different

Catalan	1	2	3	4	5	6
different	[buɾ]	[gɛtʃ]	[ʎan]	[soʎ]	[feɾ]	[biɲ]
	[buɾ]	[gɛtʃ]	[soʎ]	[ʎan]	[feɾ]	[biɲ]
same	[ʎɔs]	[leɾ]	[rin]	[tɛʃ]	[ʒan]	[rup]
	[ʎɔs]	[leɾ]	[rin]	[tɛʃ]	[ʒan]	[rup]

- CVC nonword sequences are 5, 6, and 7 items in length
- 8 trials (4S+4D) at each sequence length = 24 (12S+12D)
- All vowels in a sequence are different.
- Score % correctly identified sequences (weighted)

(French and O'Brien, 2008; Isaacs & Trofimovich, 2010; O'Brien *et al.*, 2006, 2007)

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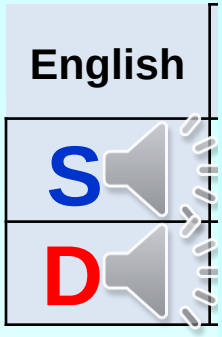
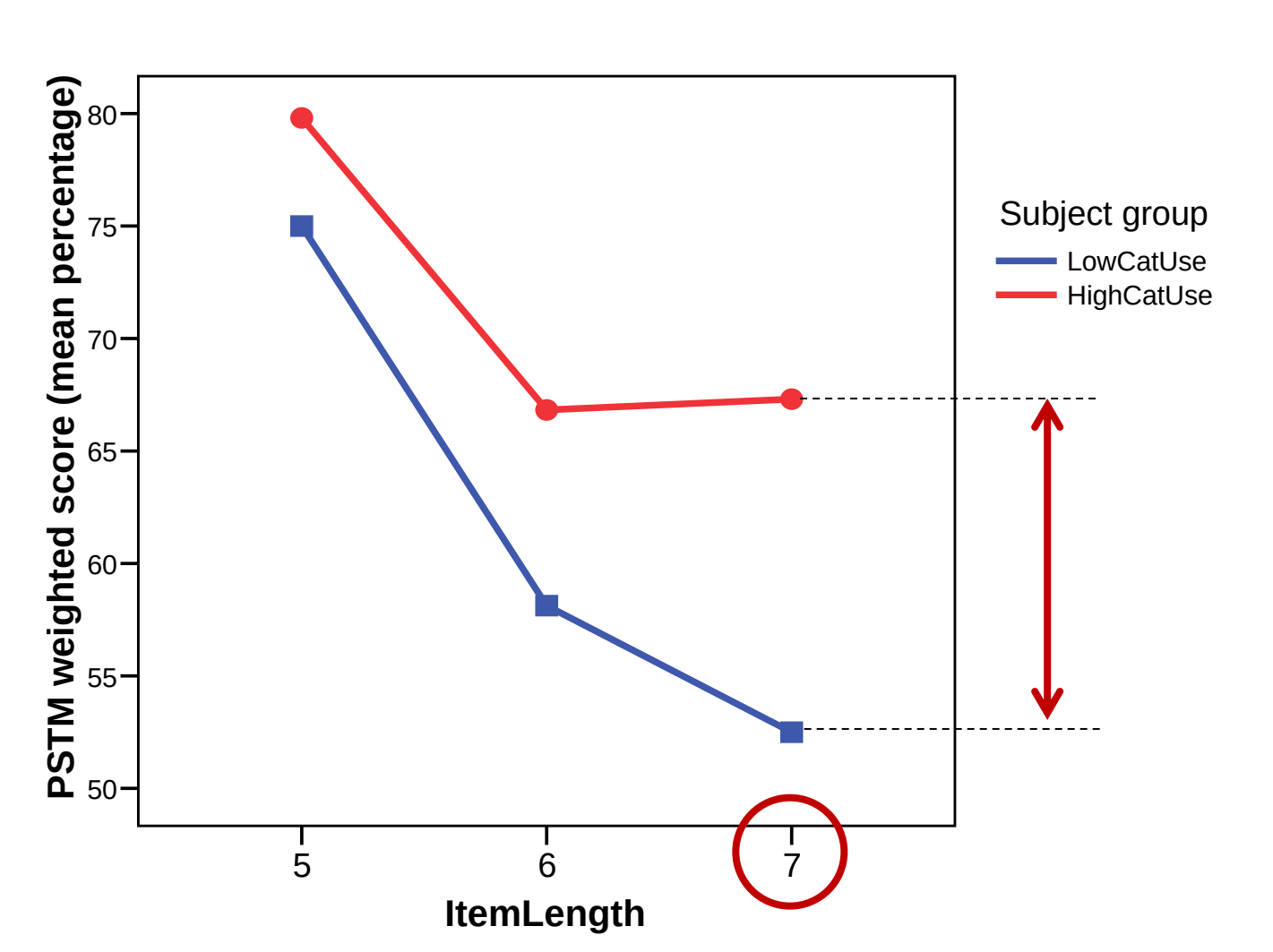


> requires phonological encoding (and subvocal rehearsal).

Phonological short-term memory (PM)

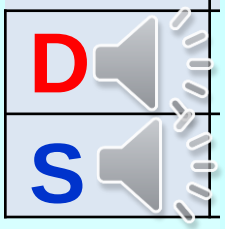
SNWR task provides a language-dependent measure of PM



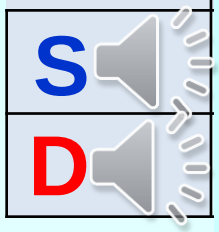
Cerviño-Povedano, Mora & Aliaga-Garcia (2011)

Phonological short-term memory (PM)

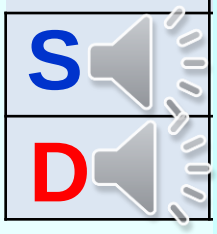
Catalan



Russian



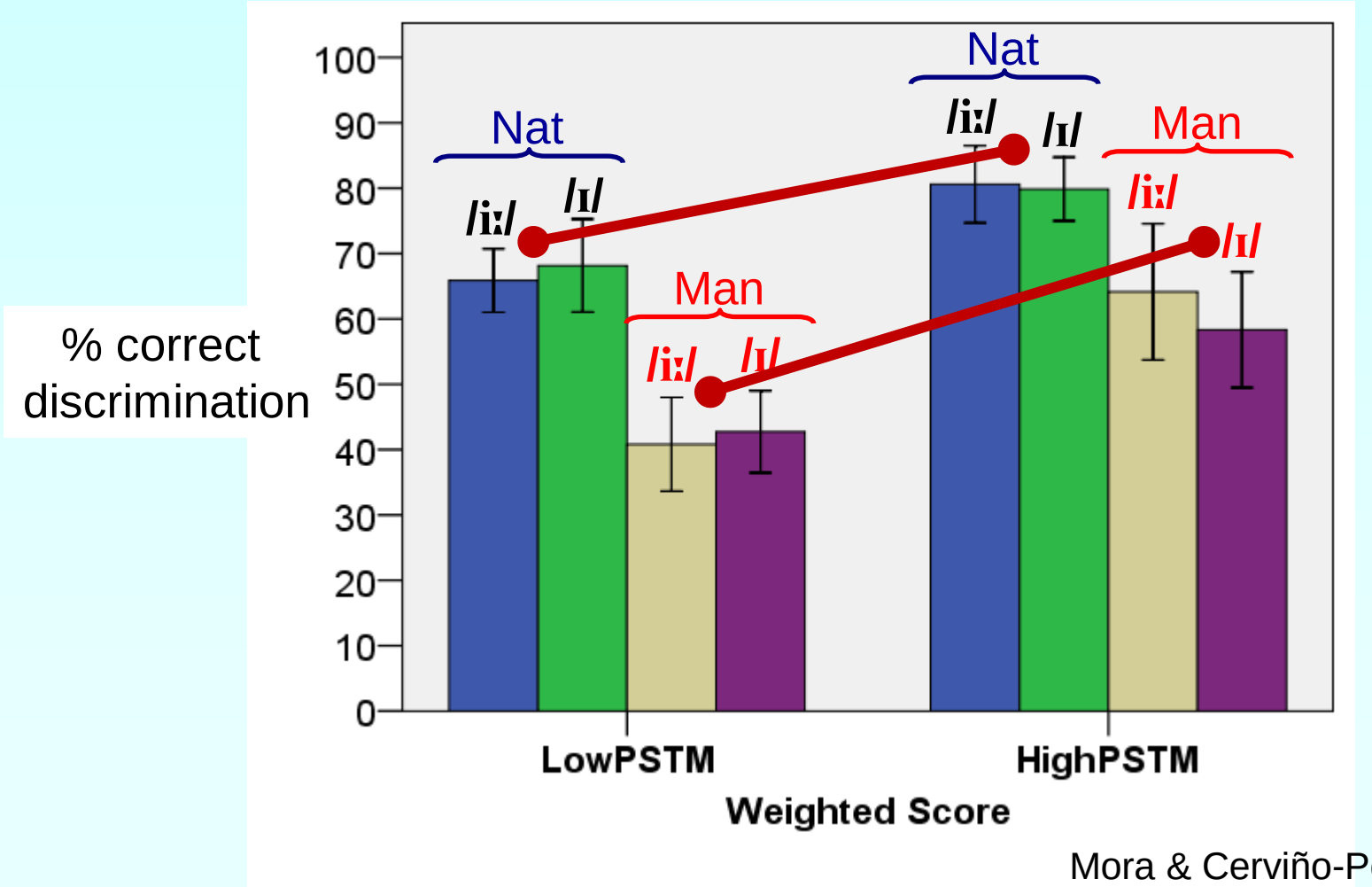
Danish



Phonological short-term memory (PM)

PM and AXB discrimination of natural (Nat) and duration-manipulated (Man) /iː/ and /ɪ/:

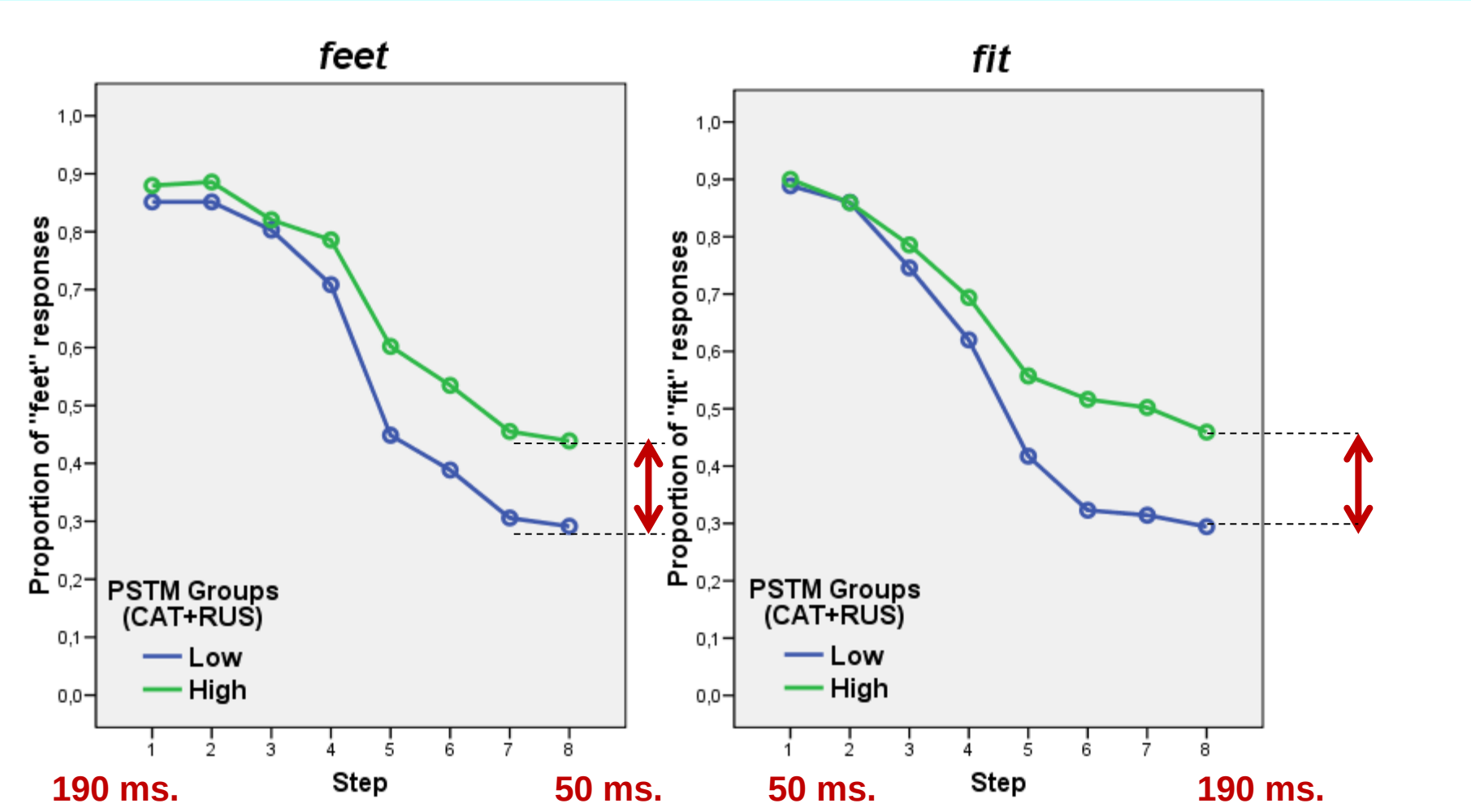
AXB ***sheep – ship – ship*** ***vs.*** ***sheep – sheep – ship***



Mora & Cerviño-Povedano (2010)

Phonological short-term memory (PM)

PM and perception of duration-manipulated /fiːt/ and /fɪt/
Forced choice identification of pictures for *feet* or *fit*.

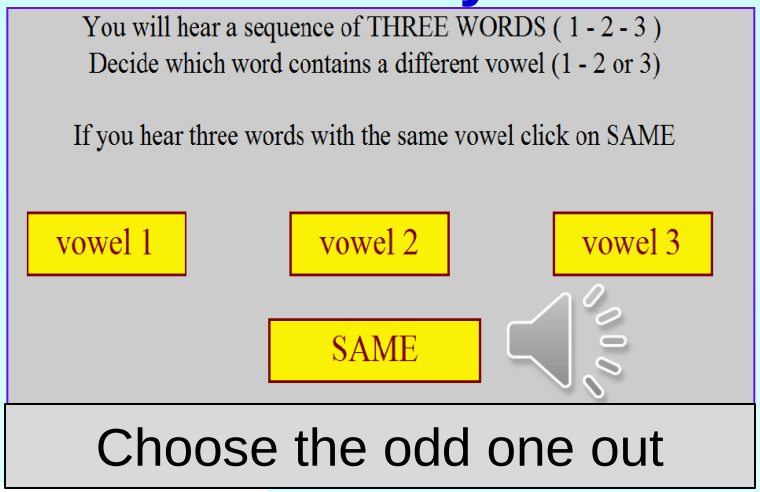


Cerviño-Povedano and Mora (2011)

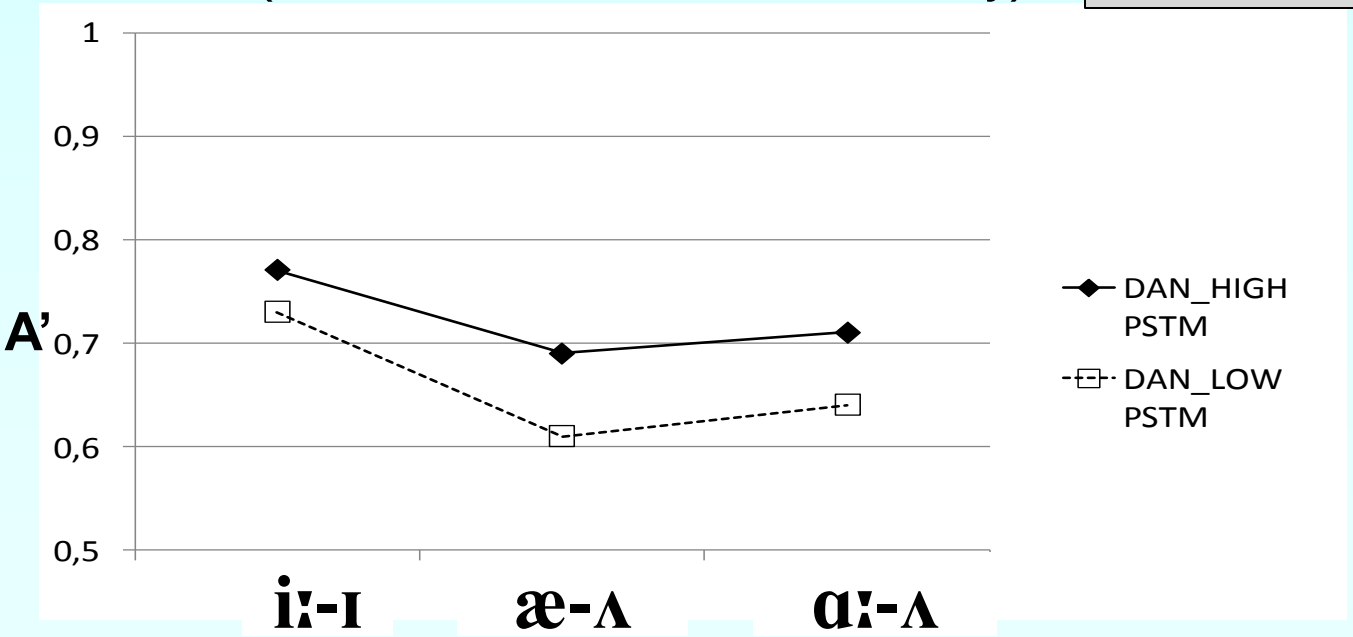
Phonological short-term memory (PM)

PM and perception of vowel contrasts in an oddity discrimination task.

CHANGE TRIALS
bid_bead_bead
bead_bid_bead
bead_bead_bid



A’ score (1=native-like; 0.5=no sensitivity)



Cerviño-Povedano, in progress

Acoustic memory (AM)

AM is a memory storage for acoustic information listeners use to encode phonological units.

It is involved in the auditory processing of acoustic-phonetic properties of speech sounds before phonological encoding.

> within-category acoustic differences for L2 sounds

> cross-language differences between similar sounds

> L2-specific weighting of phonetic cues (e.g. temporal and spectral information in vowels or voicing in consonants):

- underlying phonetic properties of speech sounds

(Cowan, 1984; Crowder and Morton, 1969; Fujisaki & Kawashina, 1969, 1970; Liberman et al. 1967; Pisoni, 1973, 1975; Studdert-Kennedy, 1973**)**

Acoustic memory (AM)

How can we measure AM?

Stimuli should:

- **not involve phonological encoding**
- **be non-intelligible**
- **be as acoustically complex as speech**

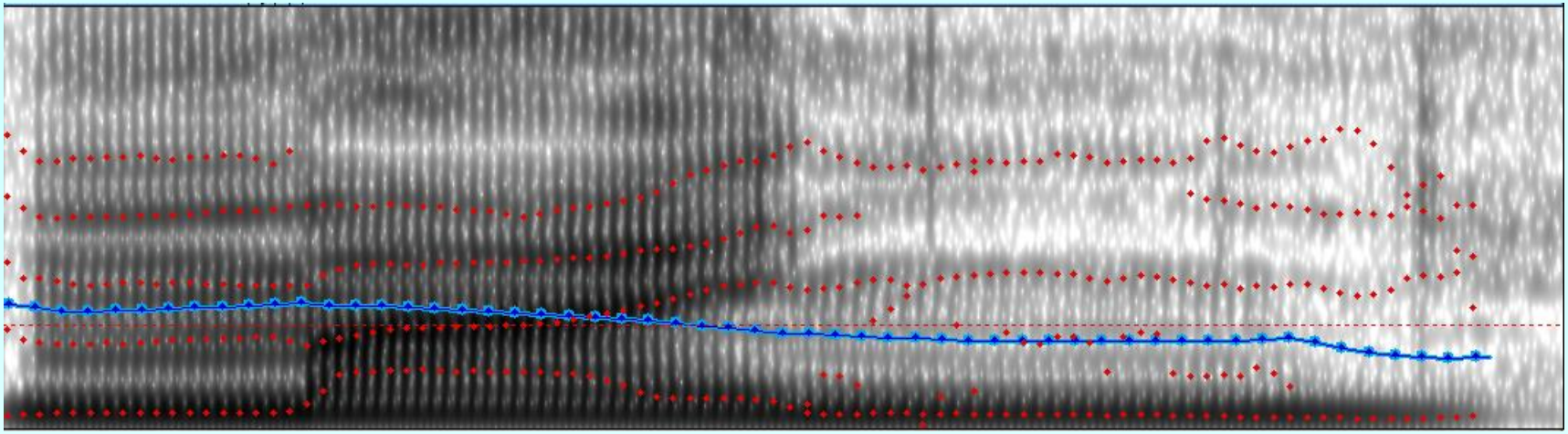
Rotated Speech (through spectral inversion)

- **non-intelligible (would require specific training).**
- **as temporally and spectrally complex as speech.**
- **preserves most speech-like properties (voicing, friction, pitch changes)**

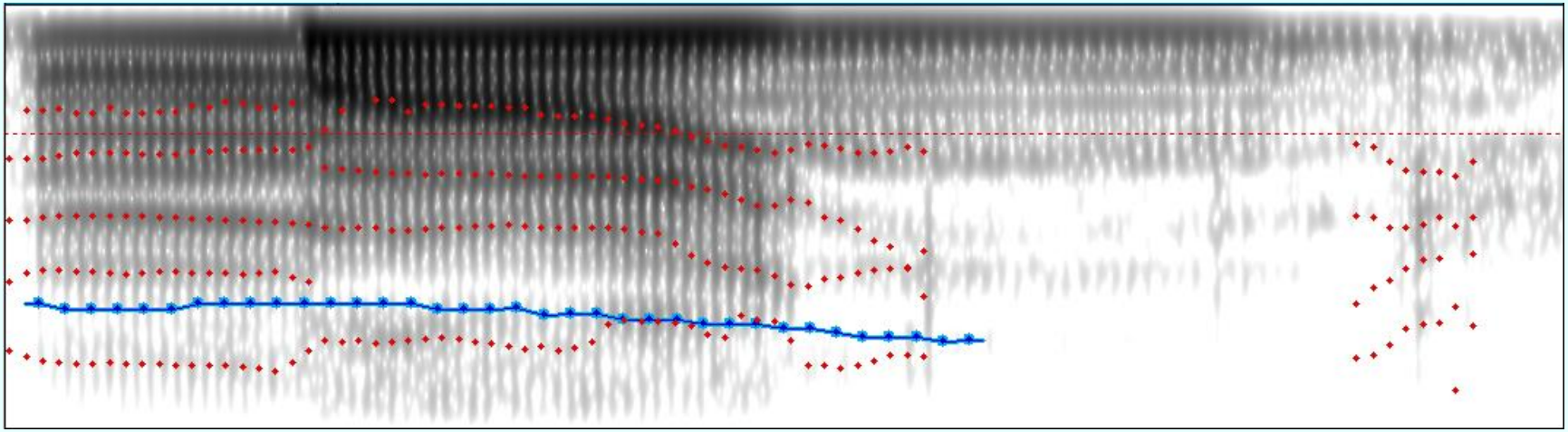
(Blesser, 1992; Cowan & Morse 1986; Crowder & Morton 1969; Jacquemot *et al.,* 2003; Scott et al. 2000)

Acoustic memory (AM)

[maɲ]



Rotated [maɲ]



Acoustic memory (AM)

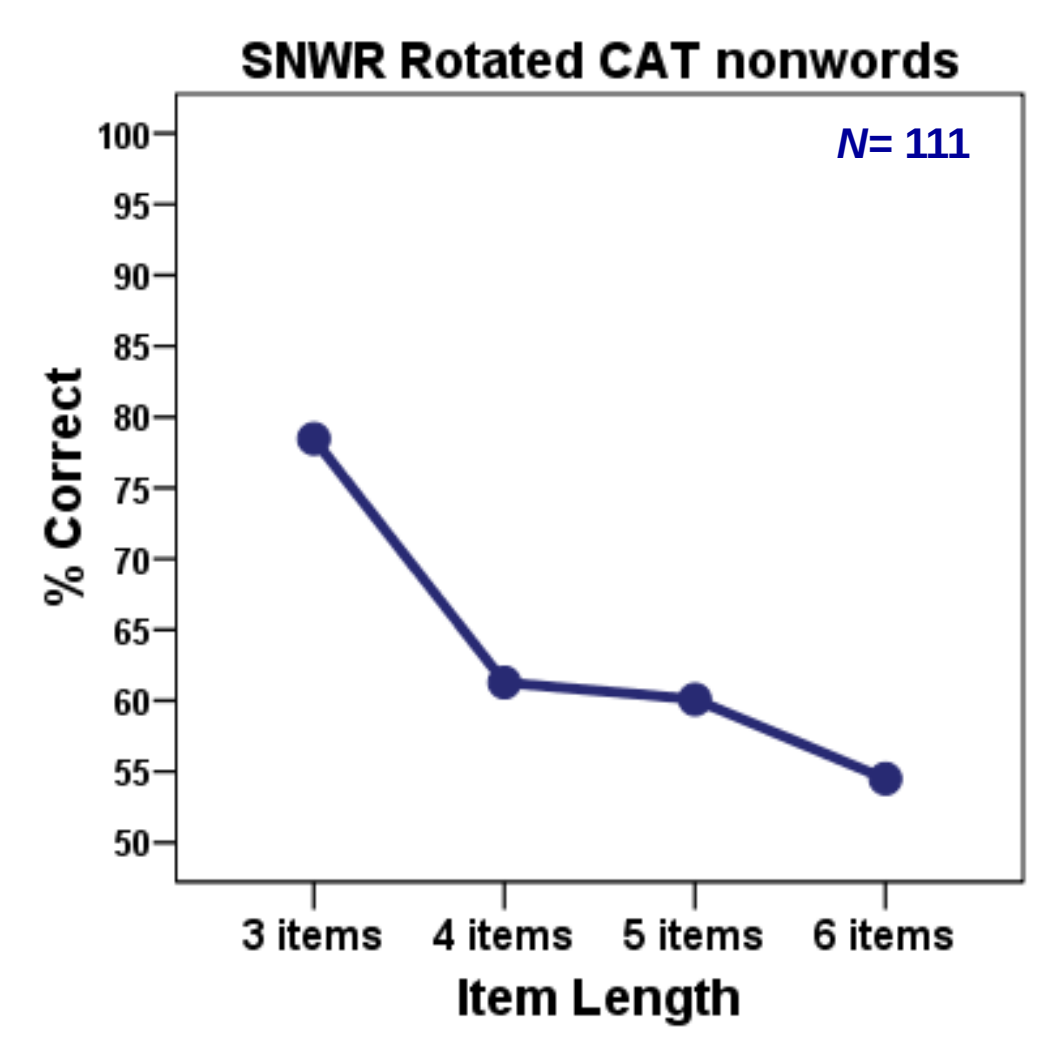
Sequences of 3 – 4 – 5 – 6 "Rotated Nonwords":

3 S

4 D

5 S

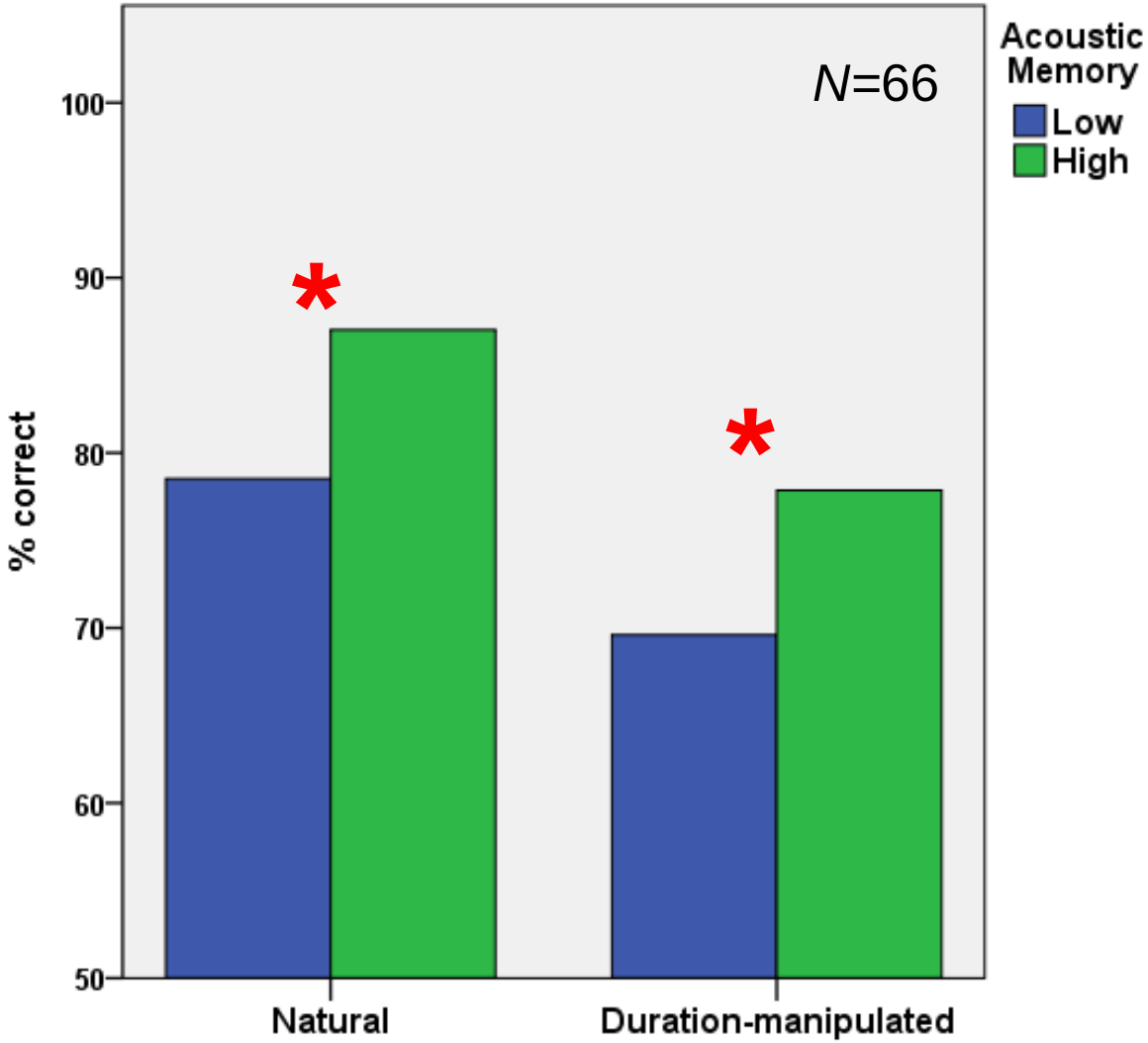
6 D



(Safronova, 2011; Safronova & Mora, 2012)

Acoustic memory (AM)

AM and AXB discrimination (/iː/ and /ɪ/)



Pearson r	AM
DIS Nat	.502***
DIS Man	.435**

ANOVA
within: Nat/Man *p*<.001
between: Low/High *p*=.009

Group differences:
Low AM (*N*=27)
High AM (*N*=39)
Nat: *p*=.007
Man: *p*=.010

(Safronova 2011; Safronova & Mora 2012)

Attention Control (AC)

Phonological attention control:

A person's ability to shift focus of attention from one attention-directing function of speech (e.g.: duration) to another (e.g. voice quality)

> L2 use is a complex cognitive task that requires the foregrounding and backgrounding of linguistic information.

> Language as an attention-directing system.

> Linguistic skill as rapid & flexible control over the attention-directing functions of language.

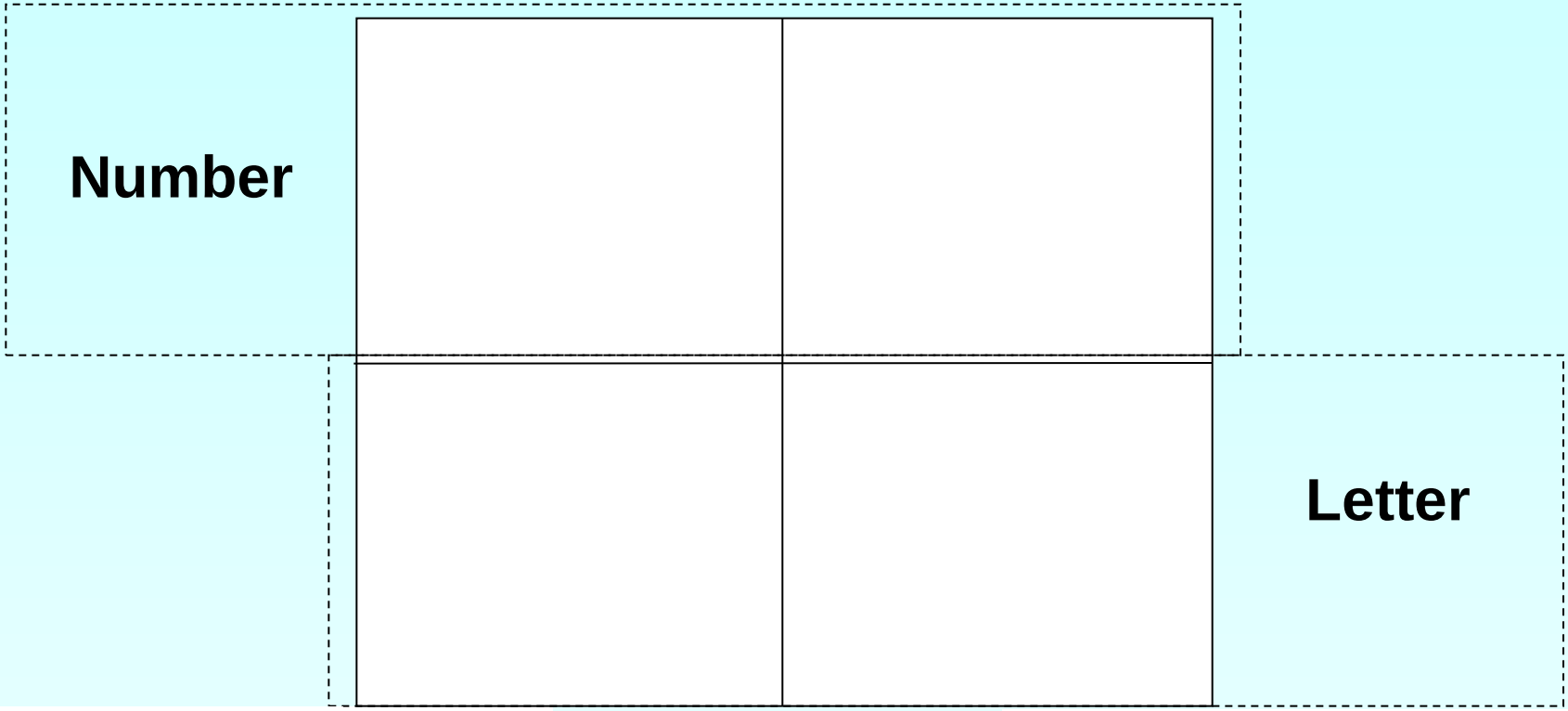
How can Attention Control be operationalized?

> alternating runs procedure requiring switching between tasks where the dimensions under focus appear predictably.

(Monsell, 2003; Rogers & Monsell, 1995; Segalowitz & Frenkiel-Fishman, 2005; Segalowitz, 2010)

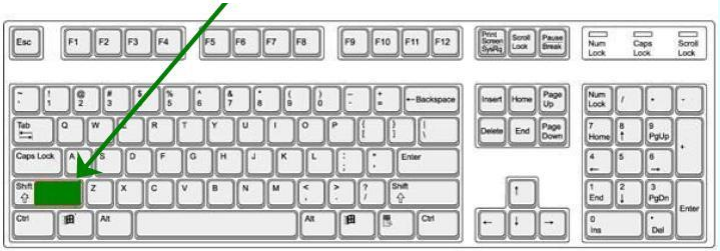
Attention Control (AC)

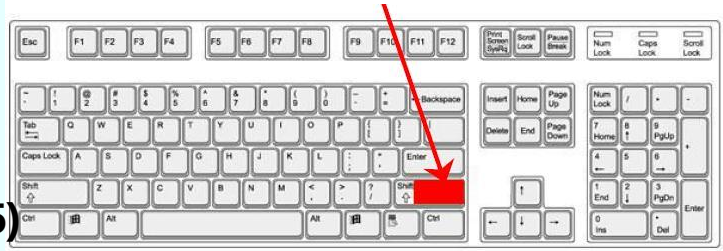
Task-switching paradigm: predictable alternating runs



odd **Left key** vowel

even **Right key** consonant





Rogers & Monsell (1995)

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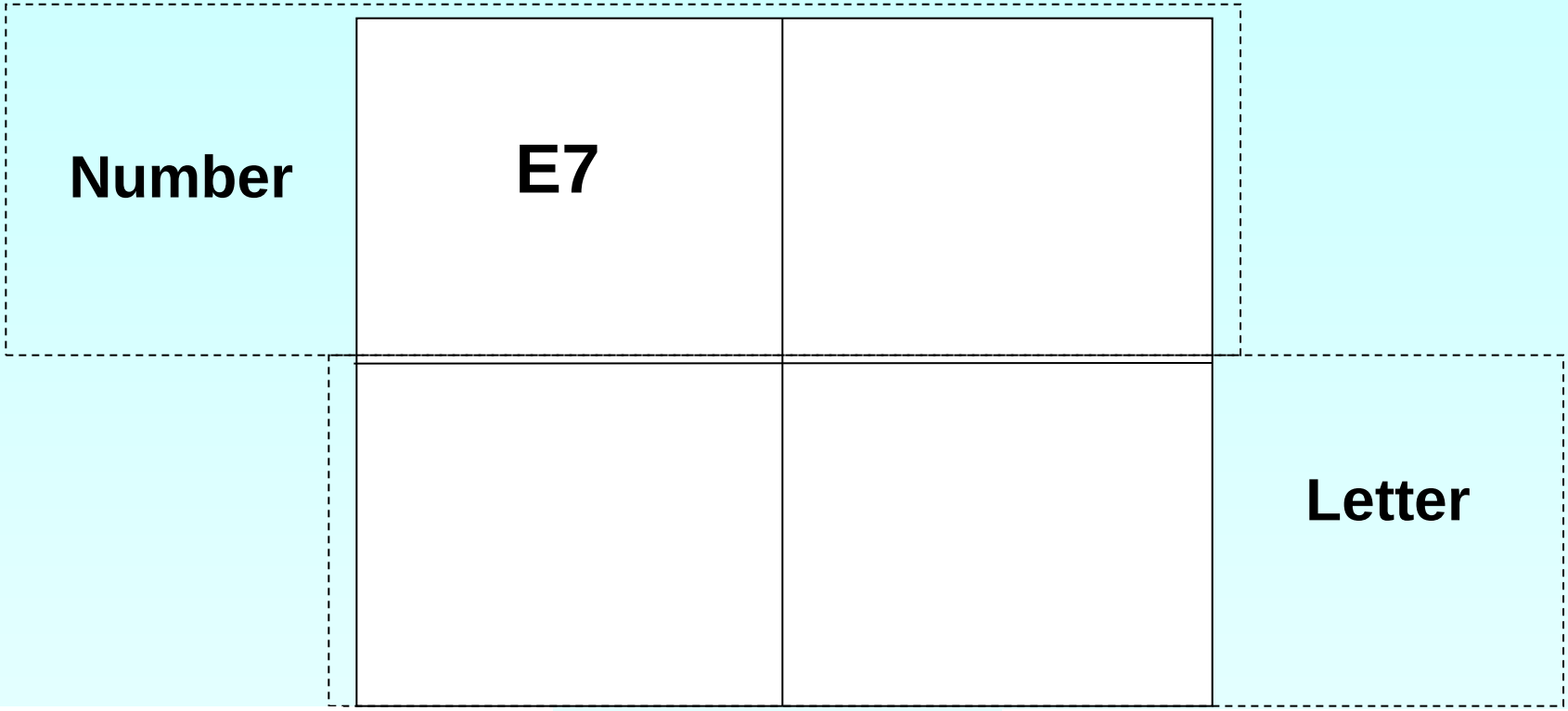

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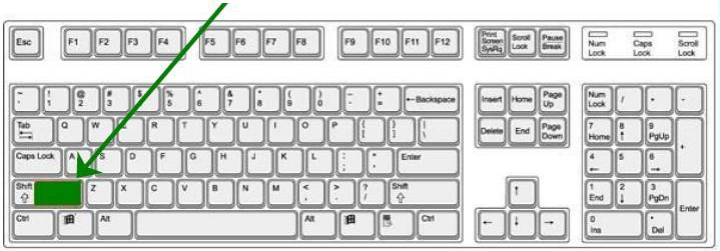

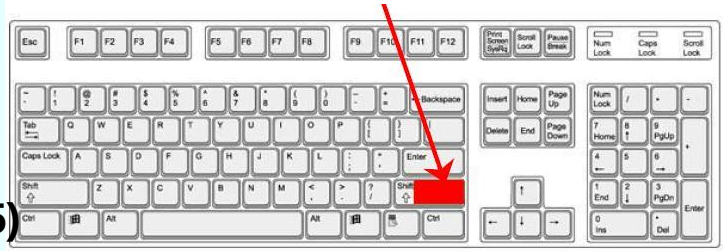

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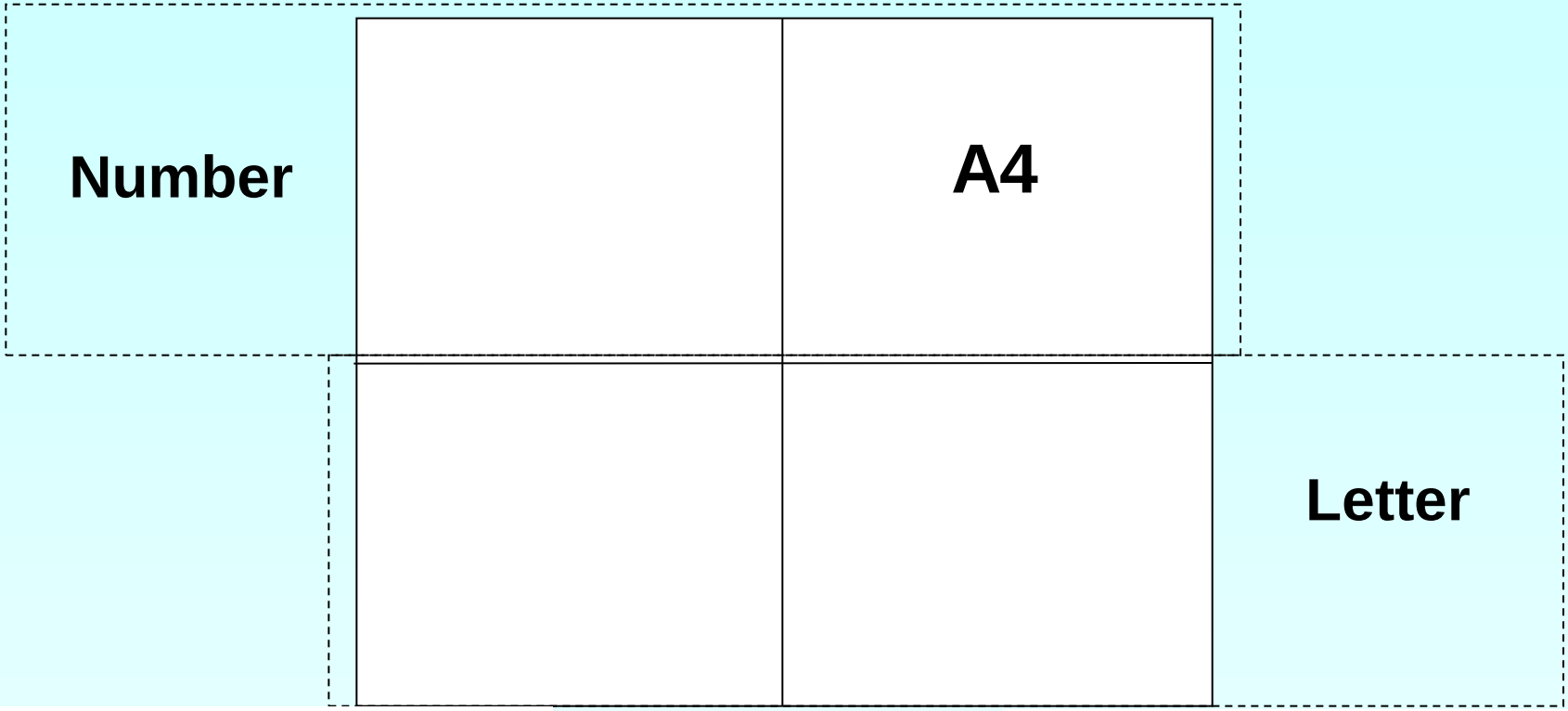

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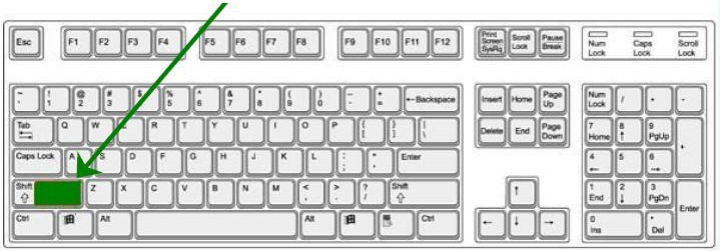

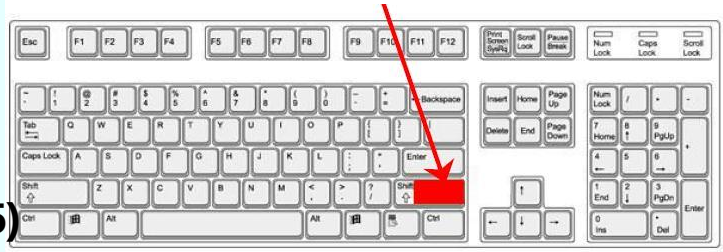

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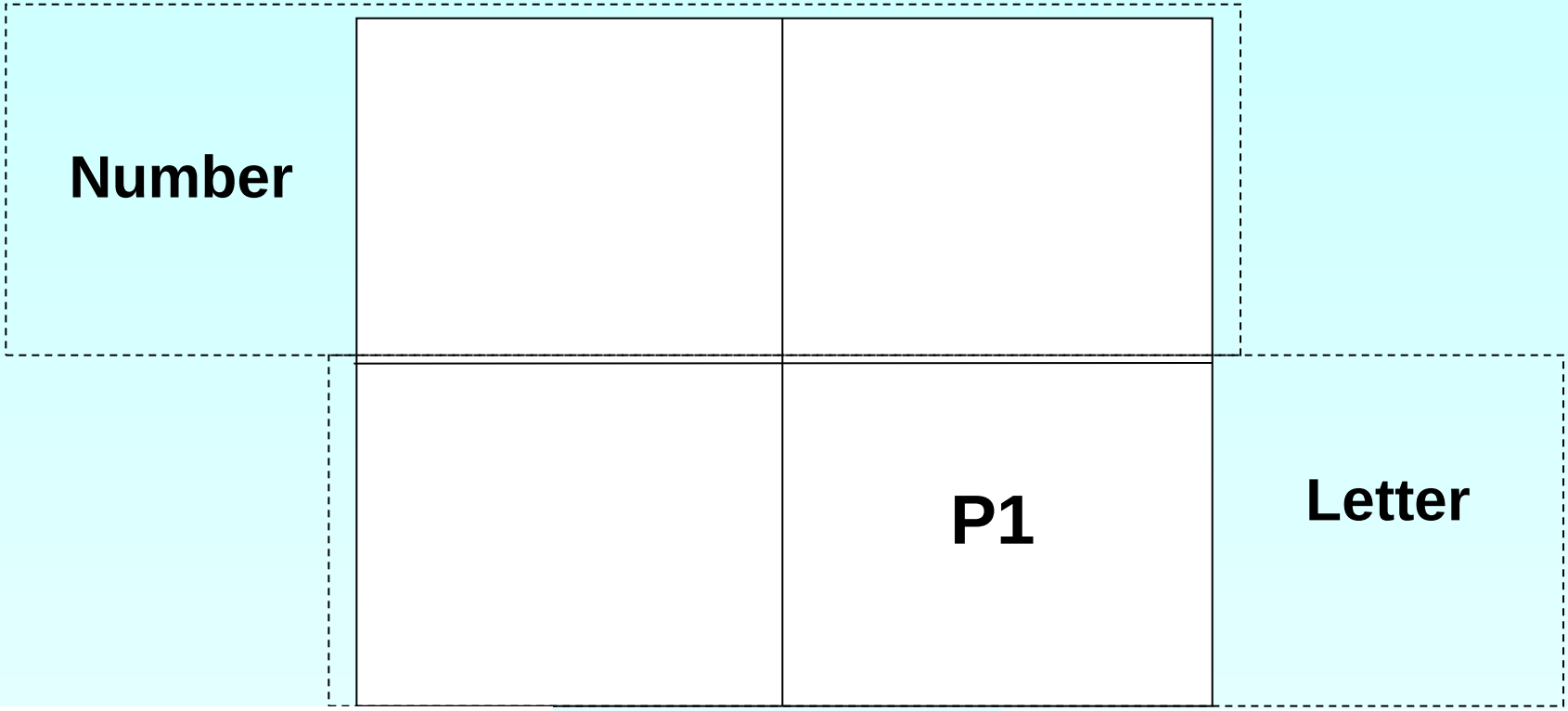

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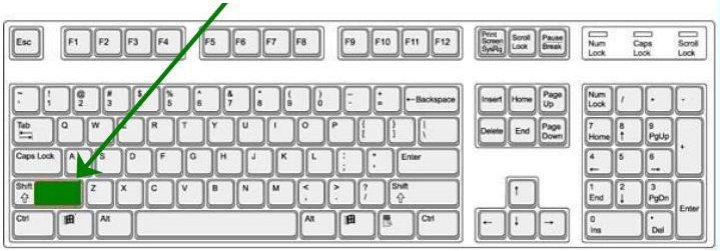

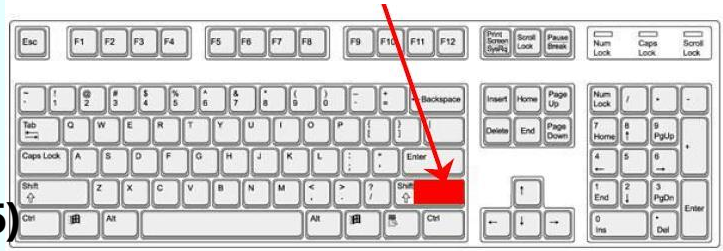

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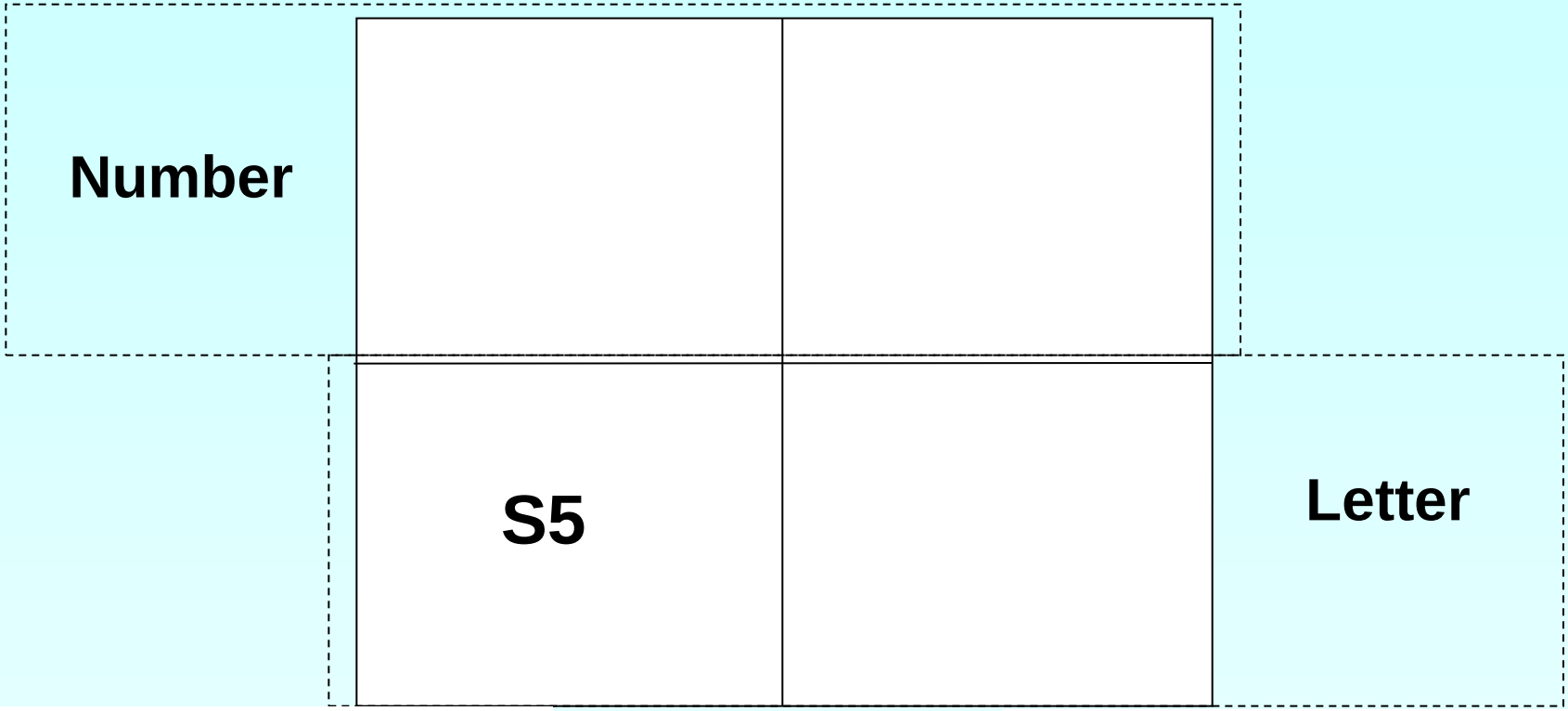

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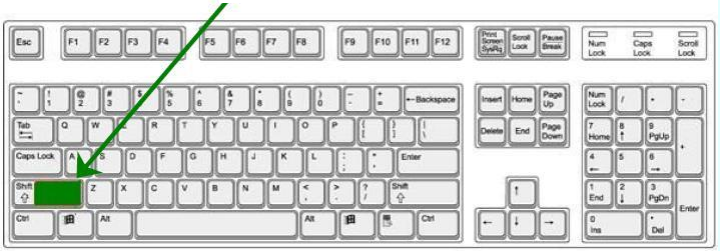

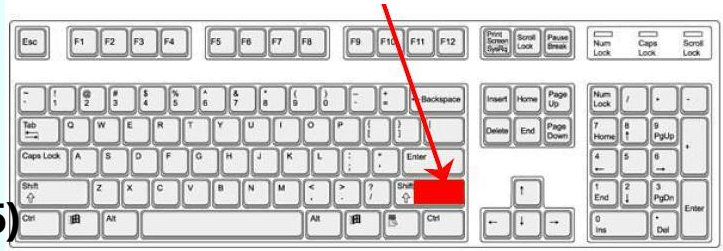

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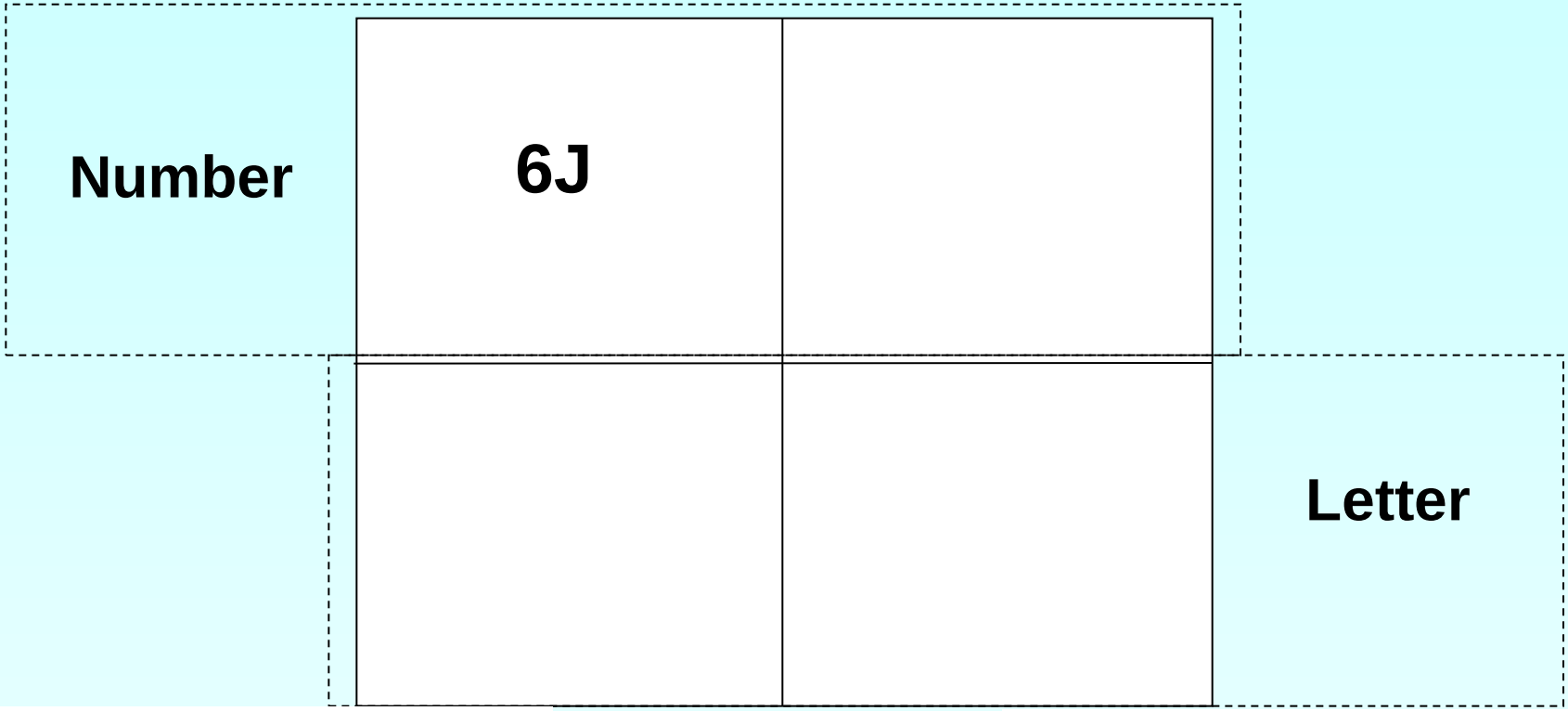

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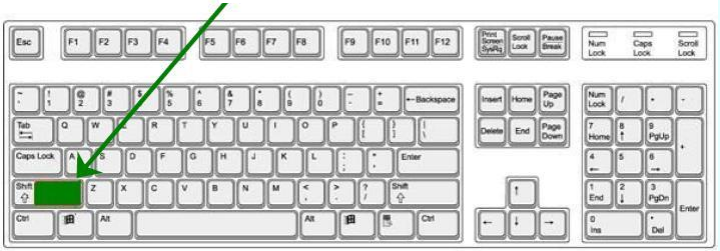
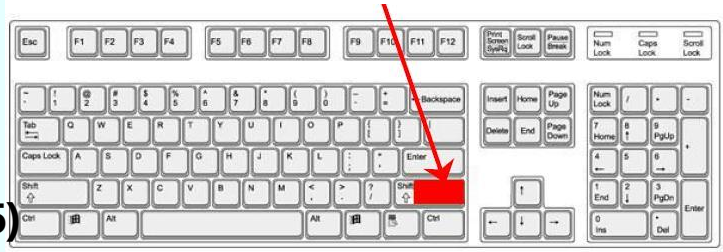
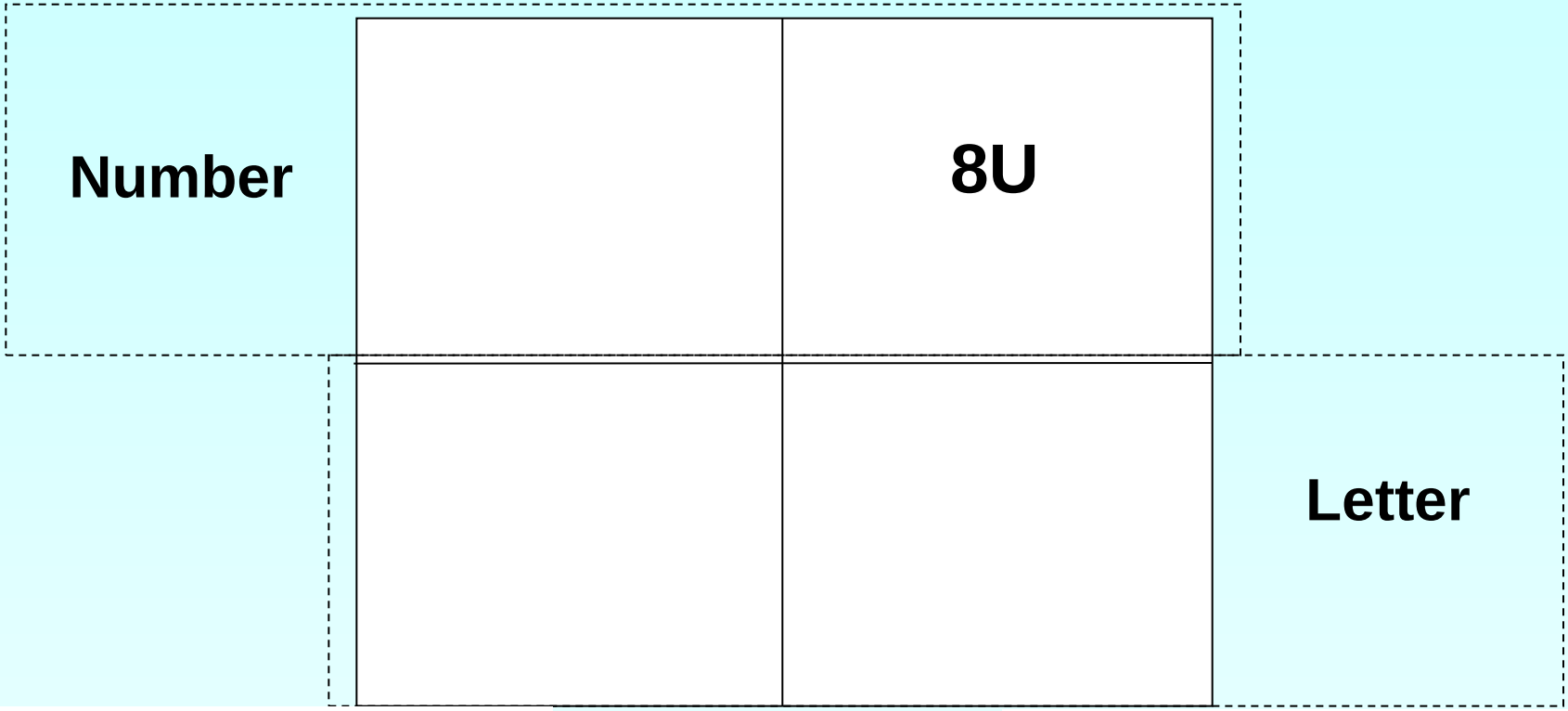




Rogers & Monsell (1995)

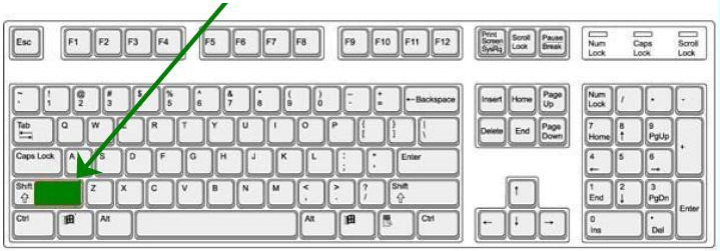
Attention Control (AC)

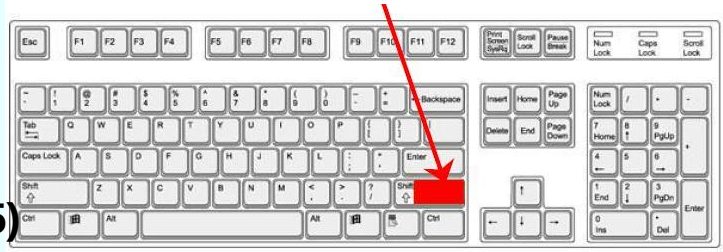
Task-switching paradigm: predictable alternating runs



odd **Left key** vowel

even **Right key** consonant





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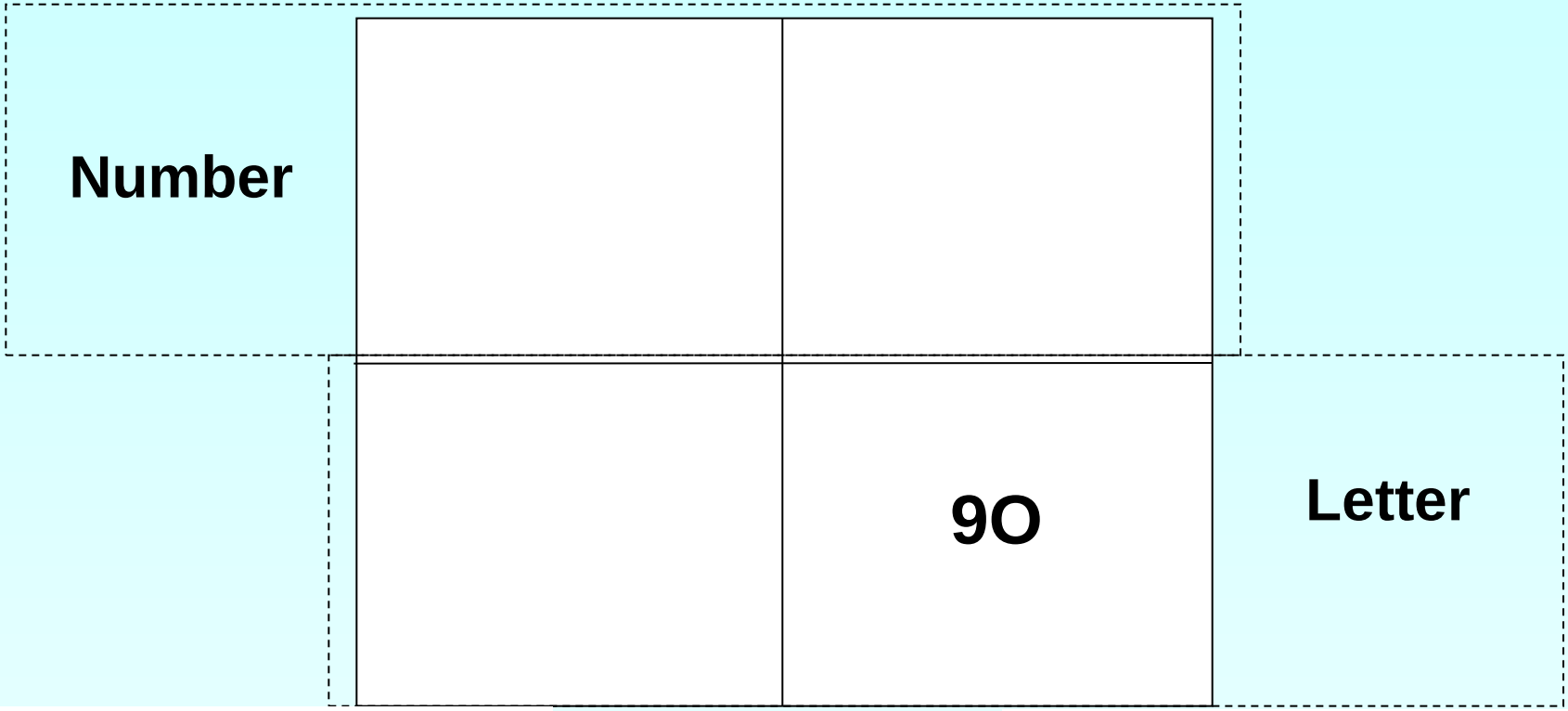
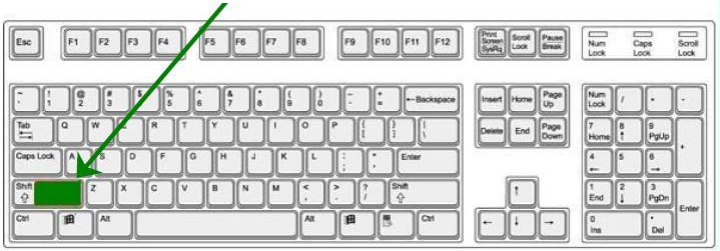
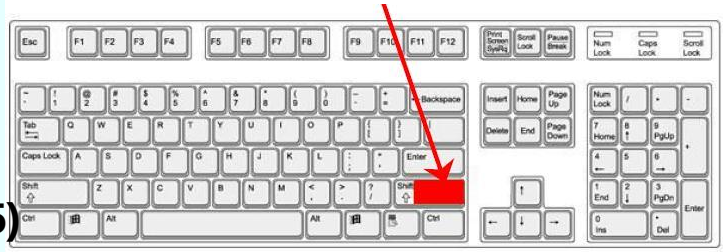


odd **Left key** vowel

even **Right key** consonant





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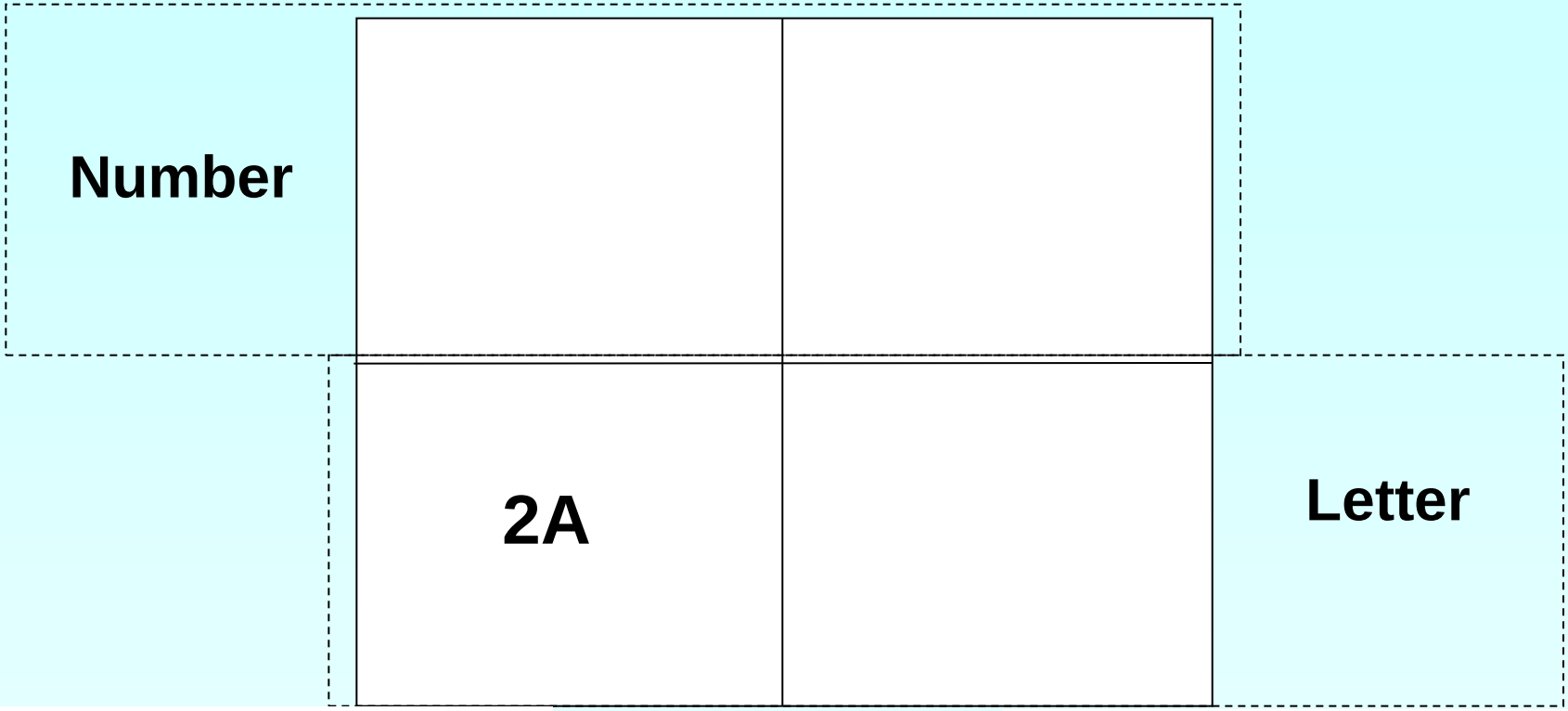
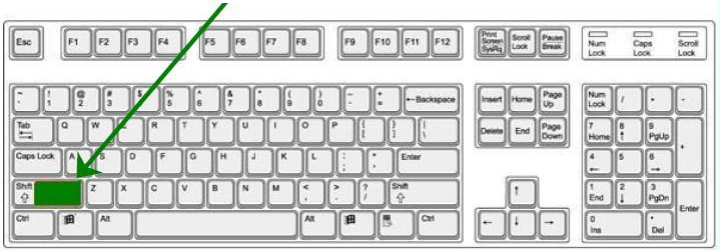
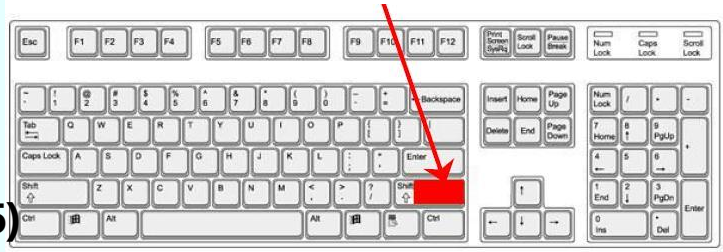


odd **Left key** vowel

even **Right key** consonant

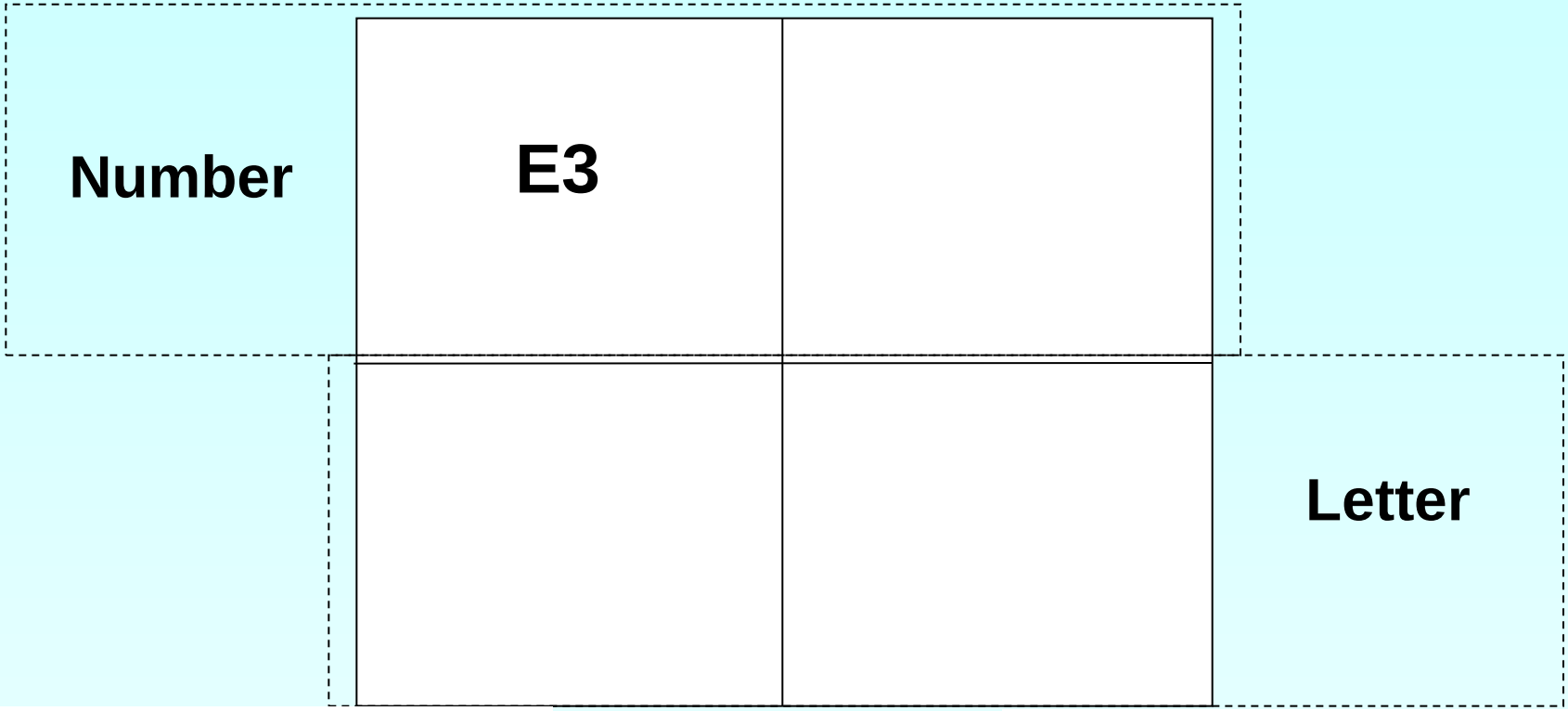




Rogers & Monsell (1995)

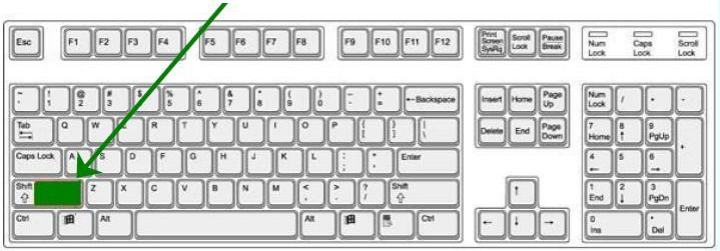
Attention Control (AC)

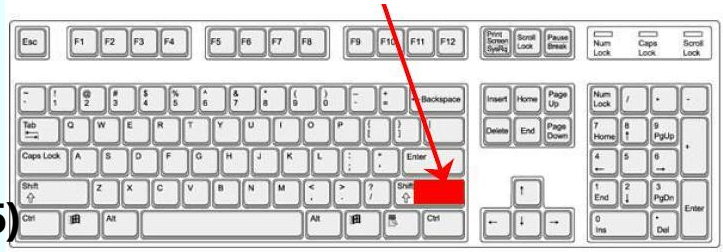
Task-switching paradigm: predictable alternating runs



odd **Left key** vowel

even **Right key** consonant

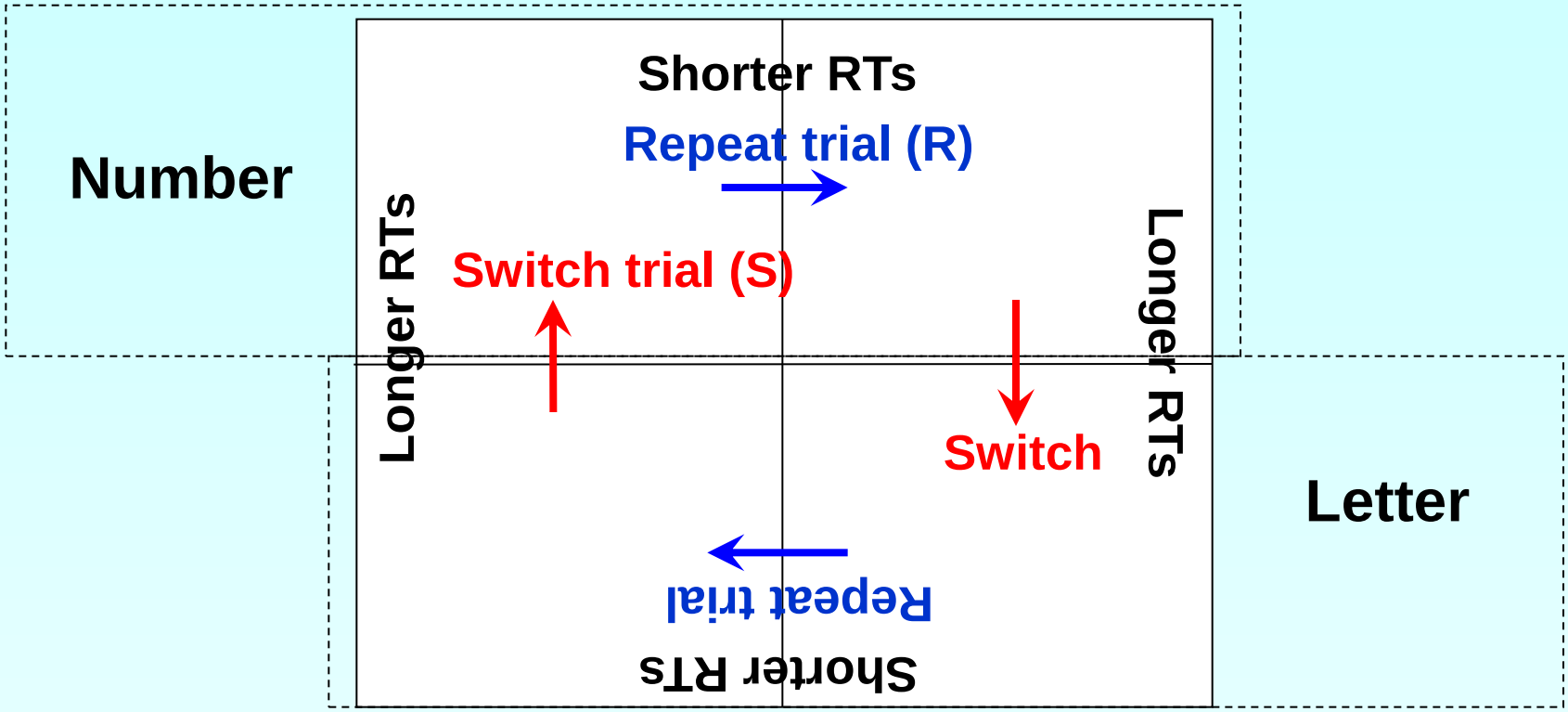




Rogers & Monsell (1995)

Attention Control (AC)

Task-switching paradigm: measures



AC Measures: - Shift cost = Switch RTs - Repeat RTs
- Error rate = Switch trials + Repeat trials

Attention Control (AC)

A speech-based version of the alternating runs paradigm

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.*

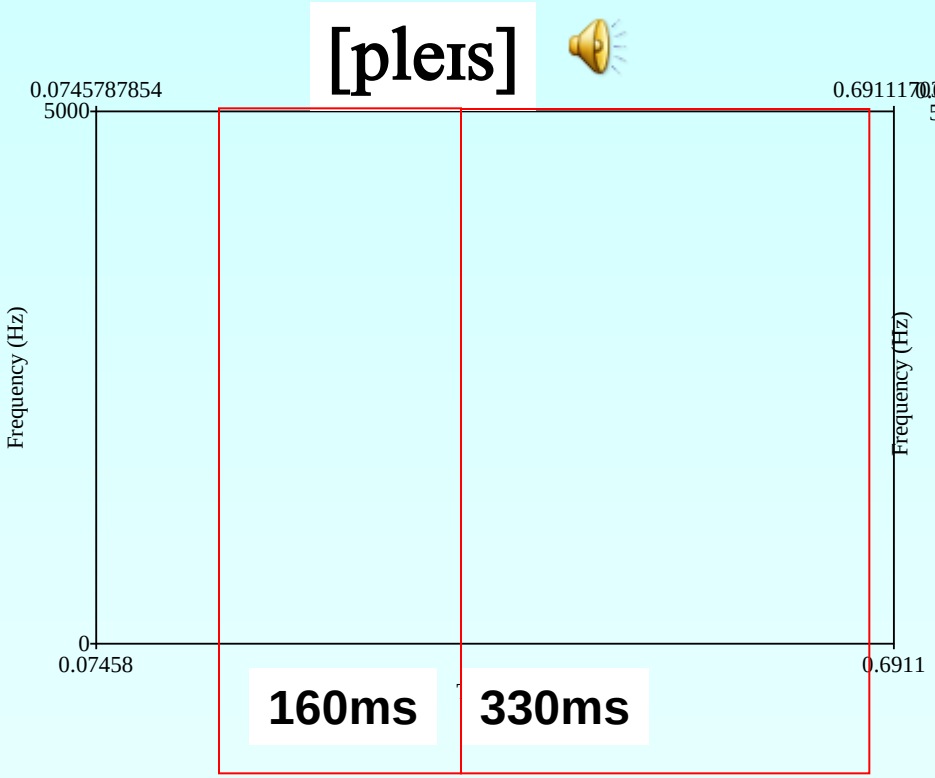
(b) female: *i, e, a, etc.*

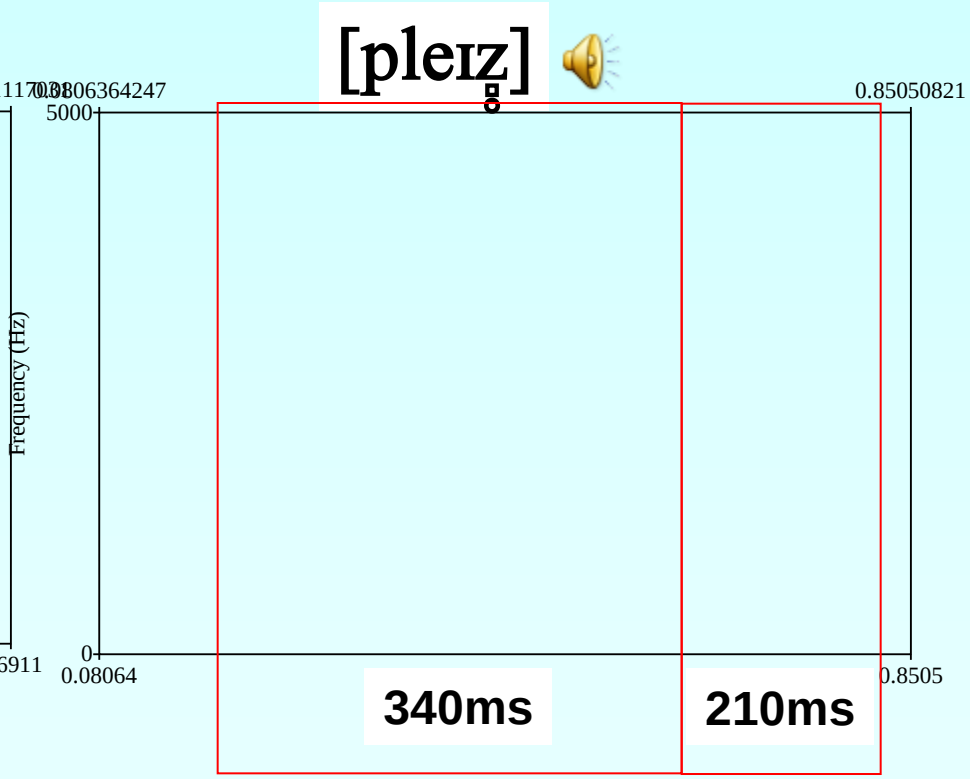
Pitch is very important in speech. Besides identifying talkers on the basis of sex and age, pitch changes are used linguistically to convey meaning, as with intonation.

(Safronova 2011; Safronova & Mora 2013)

Attention Control (AC)

A person's ability to shift focus of attention from one speech-based attention-directing function to another

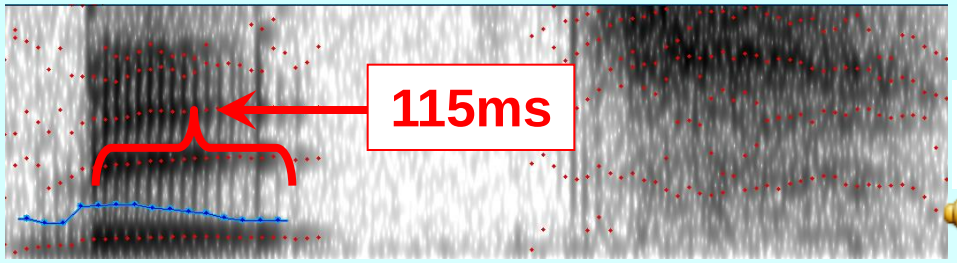




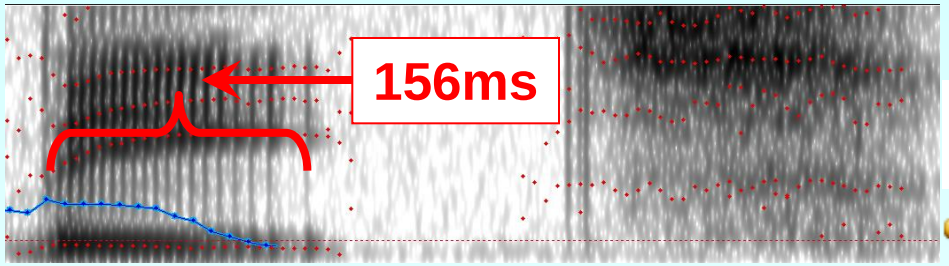
Foregrounding of duration vs. backgrounding of (partial) closure voicing in word-final obstruents.

Attention Control (AC)

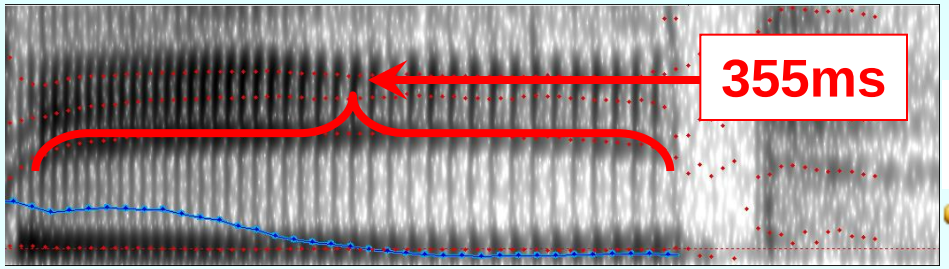
A person's ability to shift focus of attention from one speech-based attention-directing function to another



[bɪt]



[biːt]

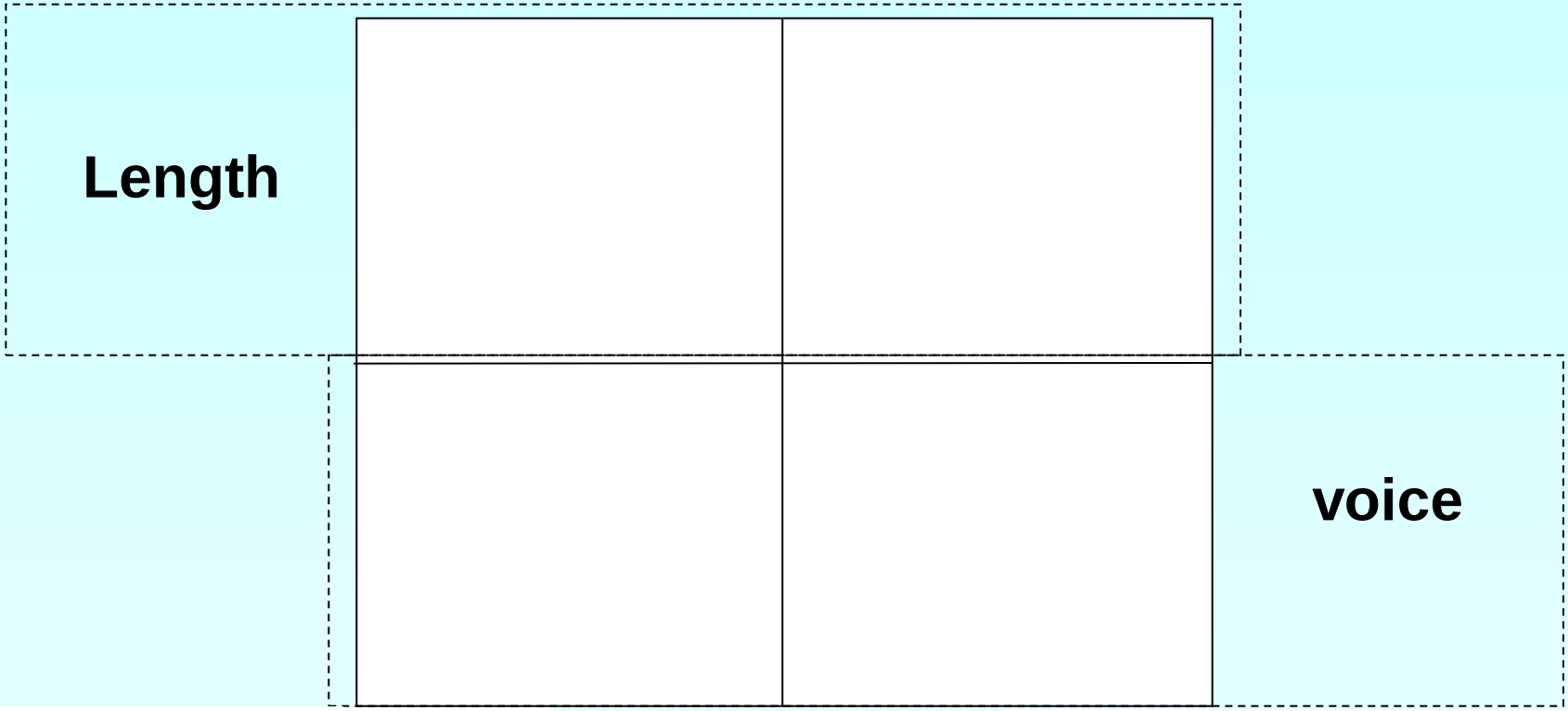


[biːd]

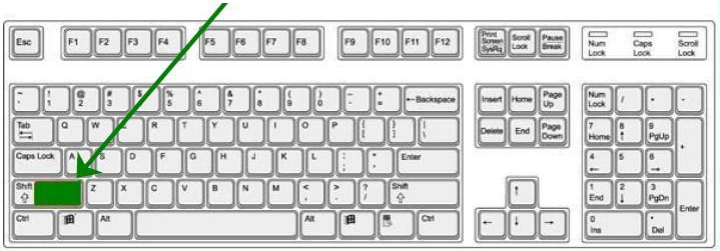
Foregrounding vs. backgrounding temporal and spectral information.

Attention Control (AC)

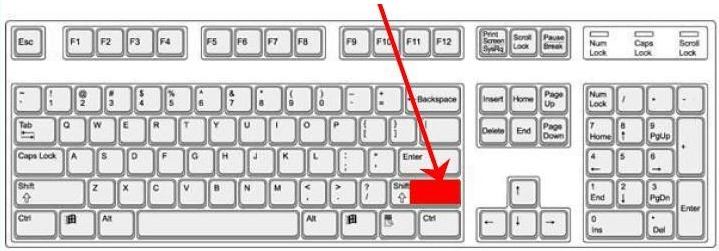
Task-switching paradigm (speech-based version)



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

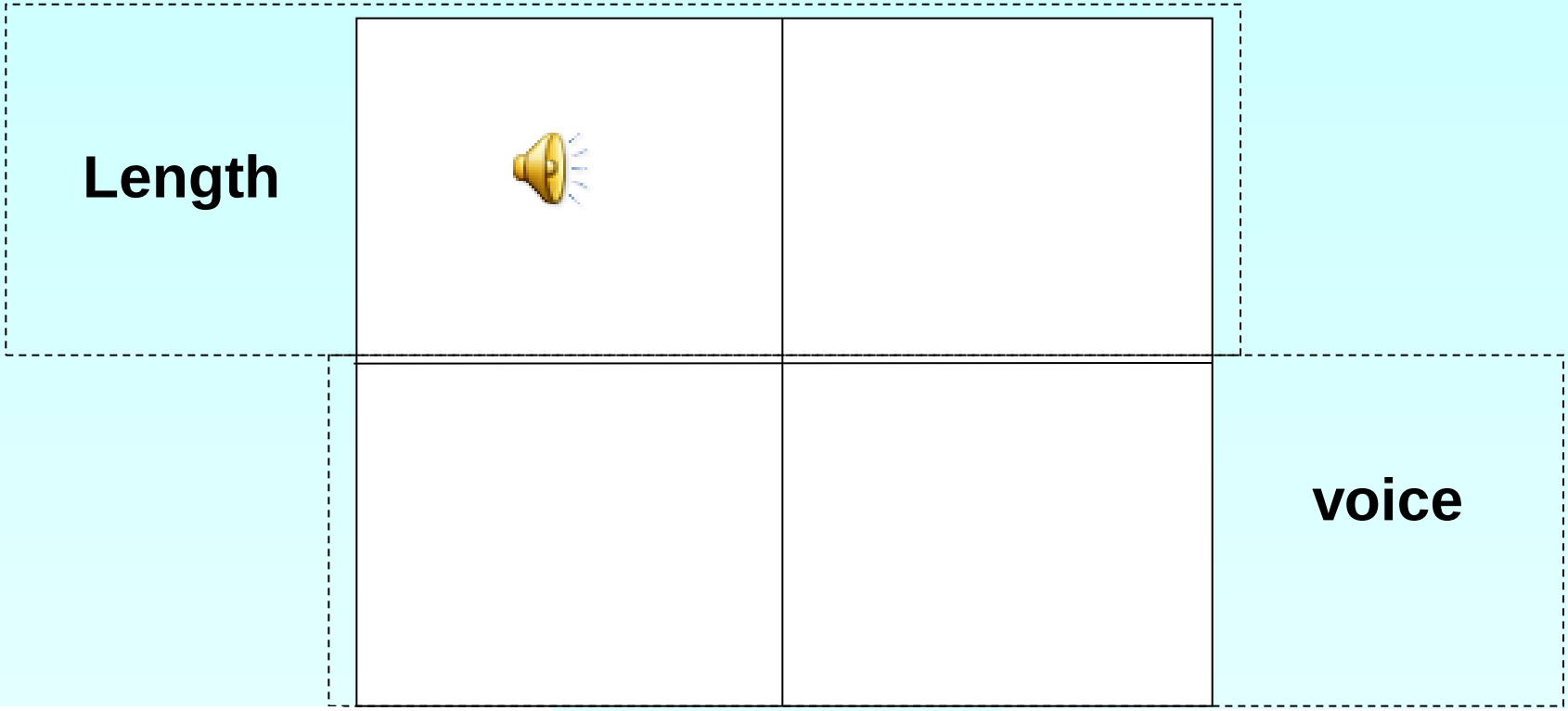


Short **Right key** **Male**

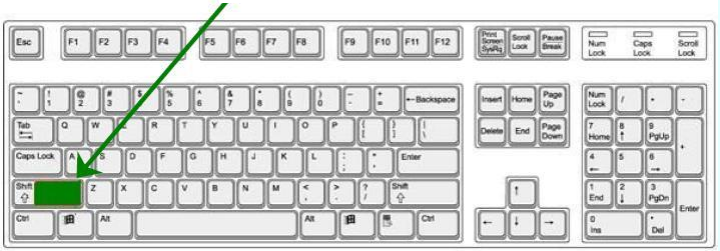


Attention Control (AC)

Task-switching paradigm (speech-based version)



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



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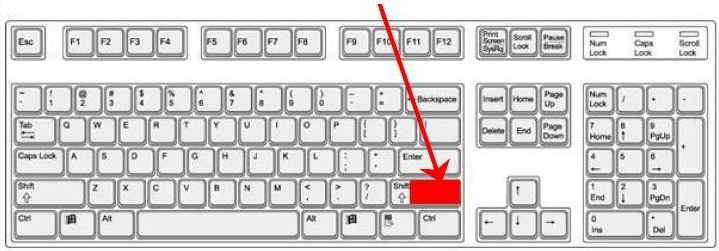
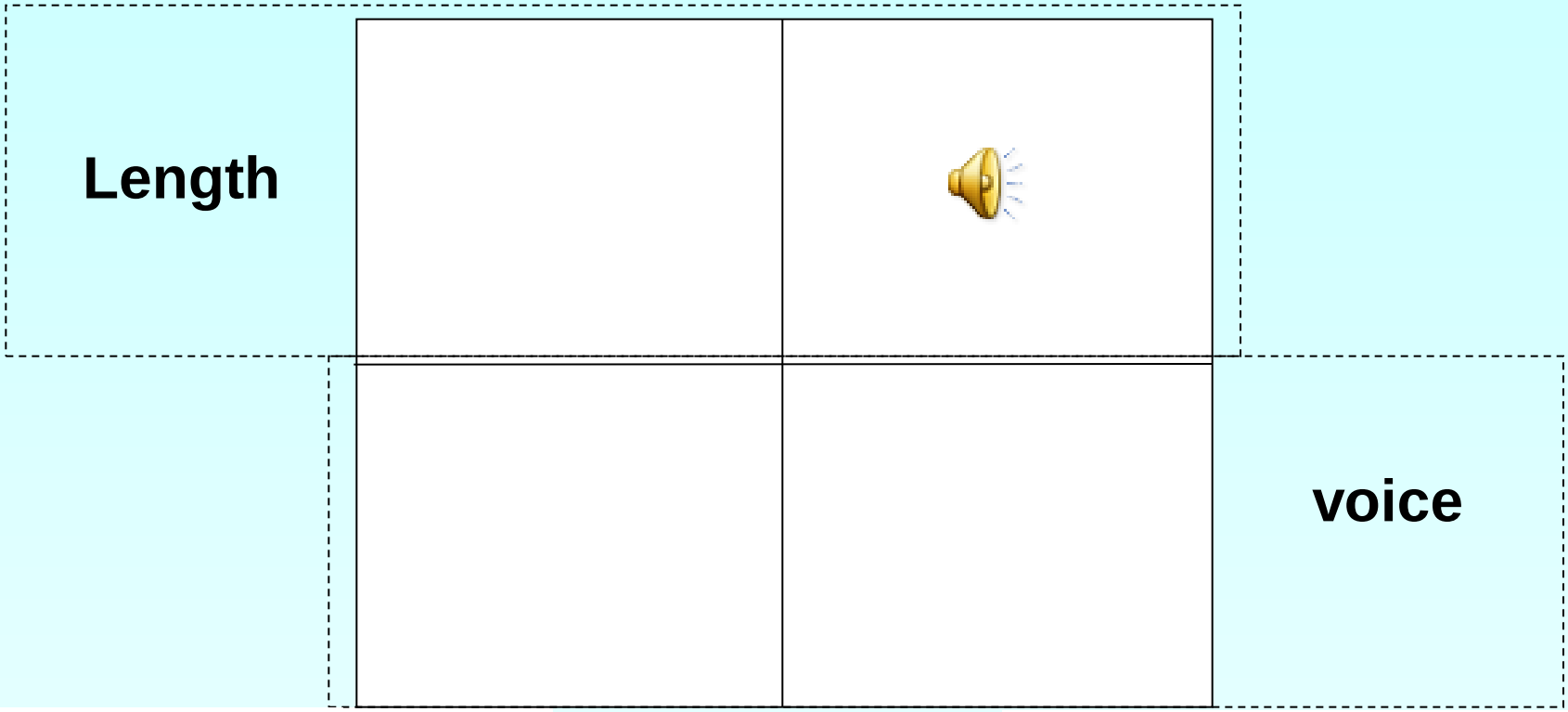
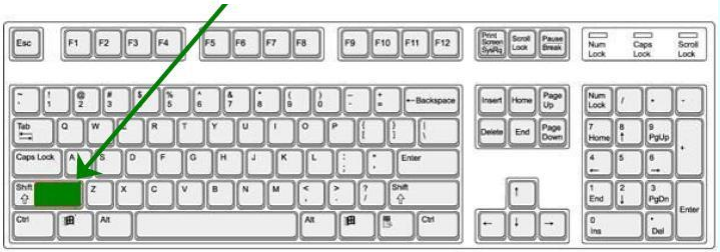


Attention Control (AC)

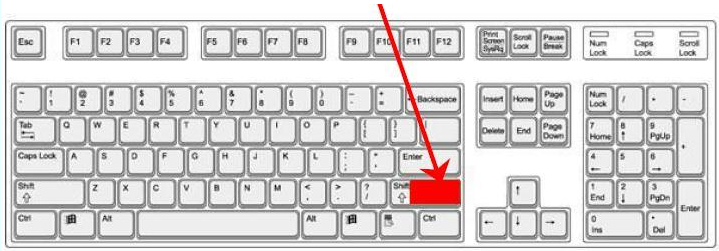
Task-switching paradigm (speech-based version)



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

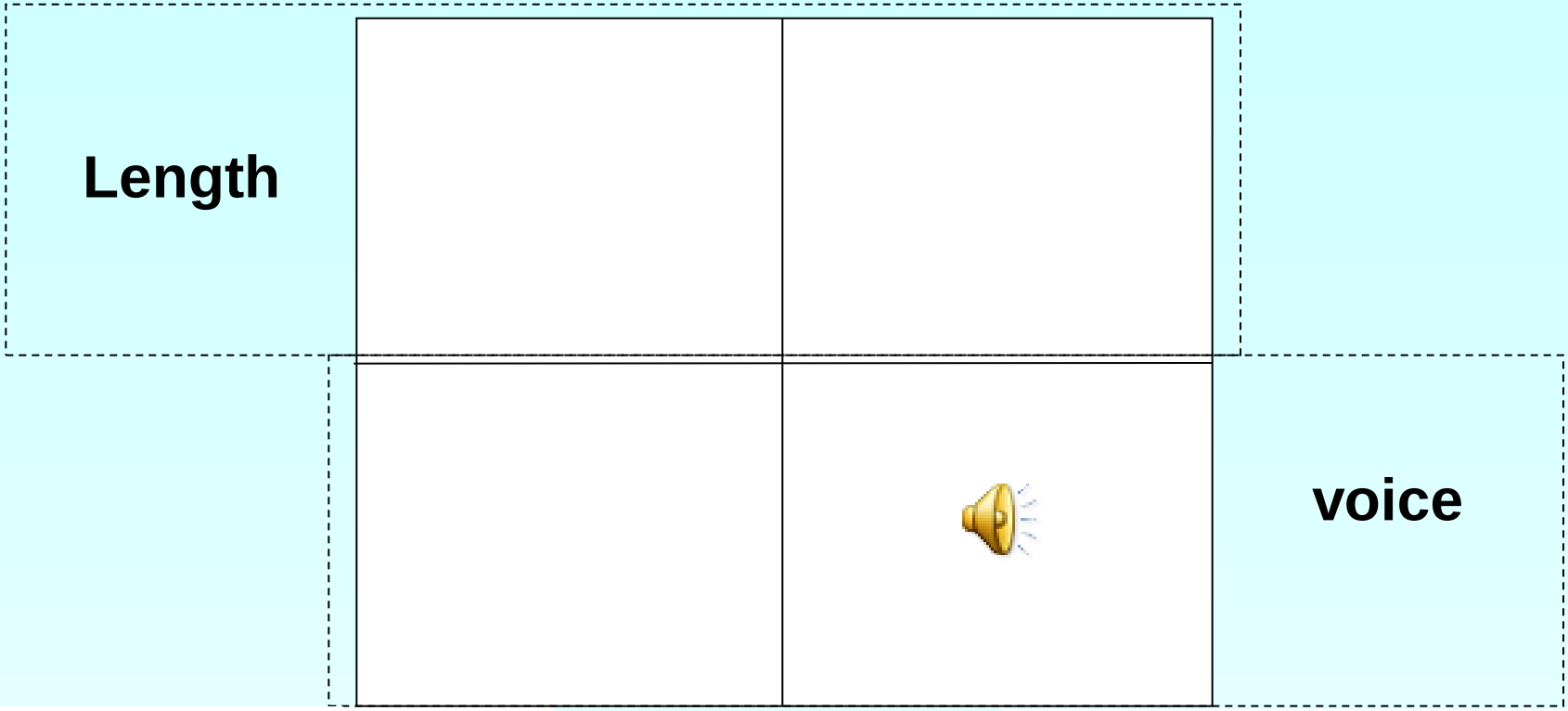


Short **Right key** **Male**

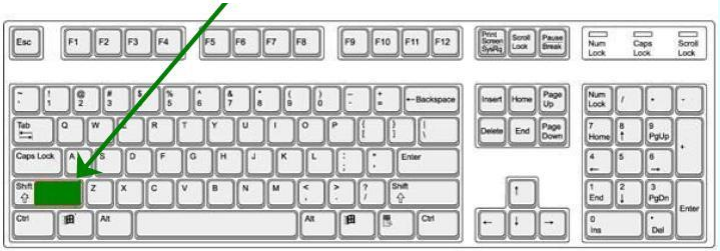


Attention Control (AC)

Task-switching paradigm (speech-based version)



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



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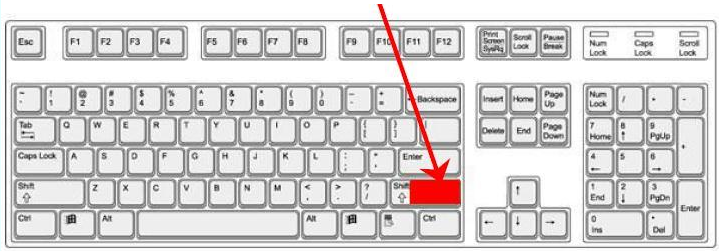
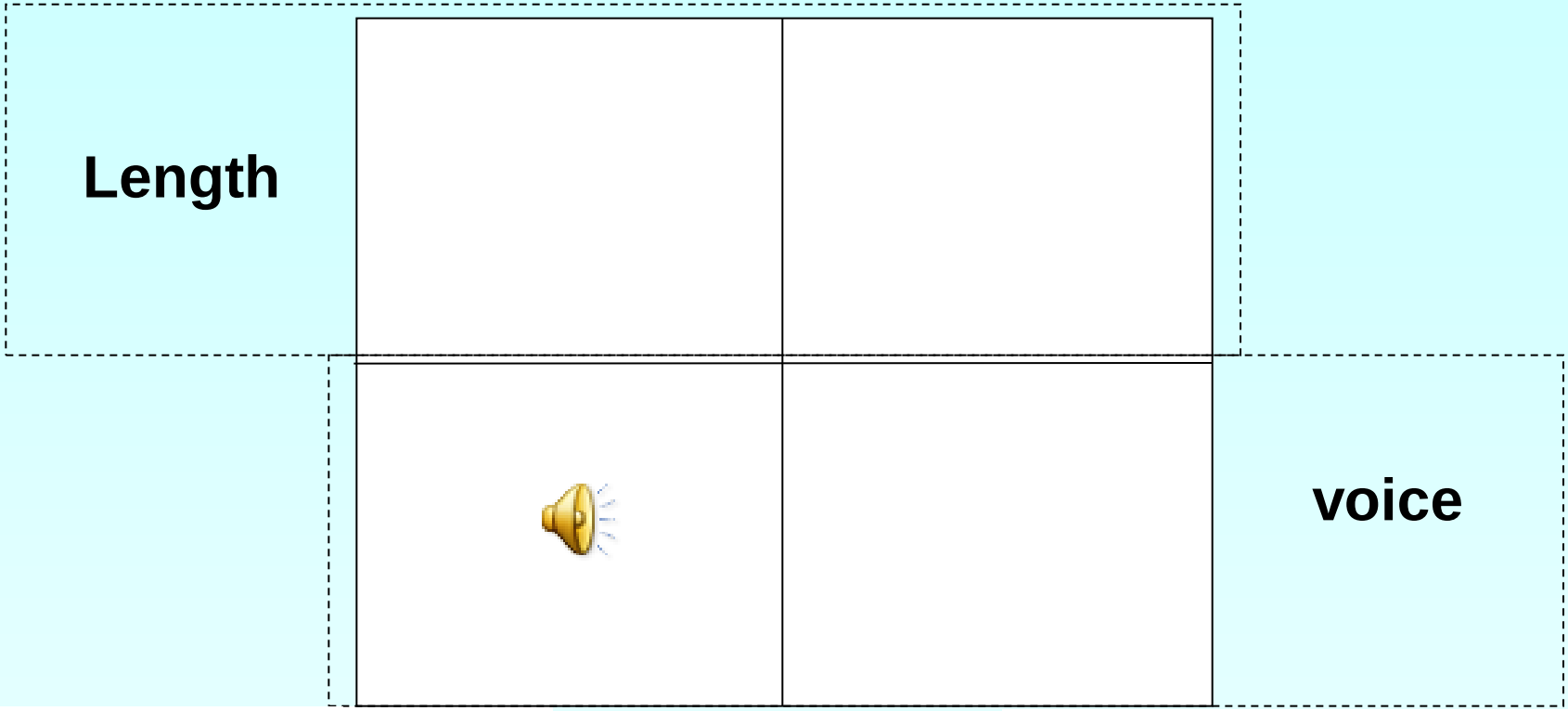


Attention Control (AC)

Task-switching paradigm (speech-based version)



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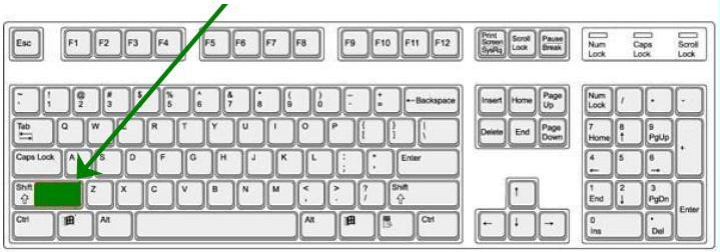

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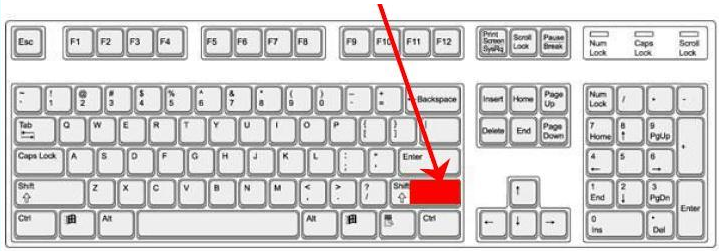

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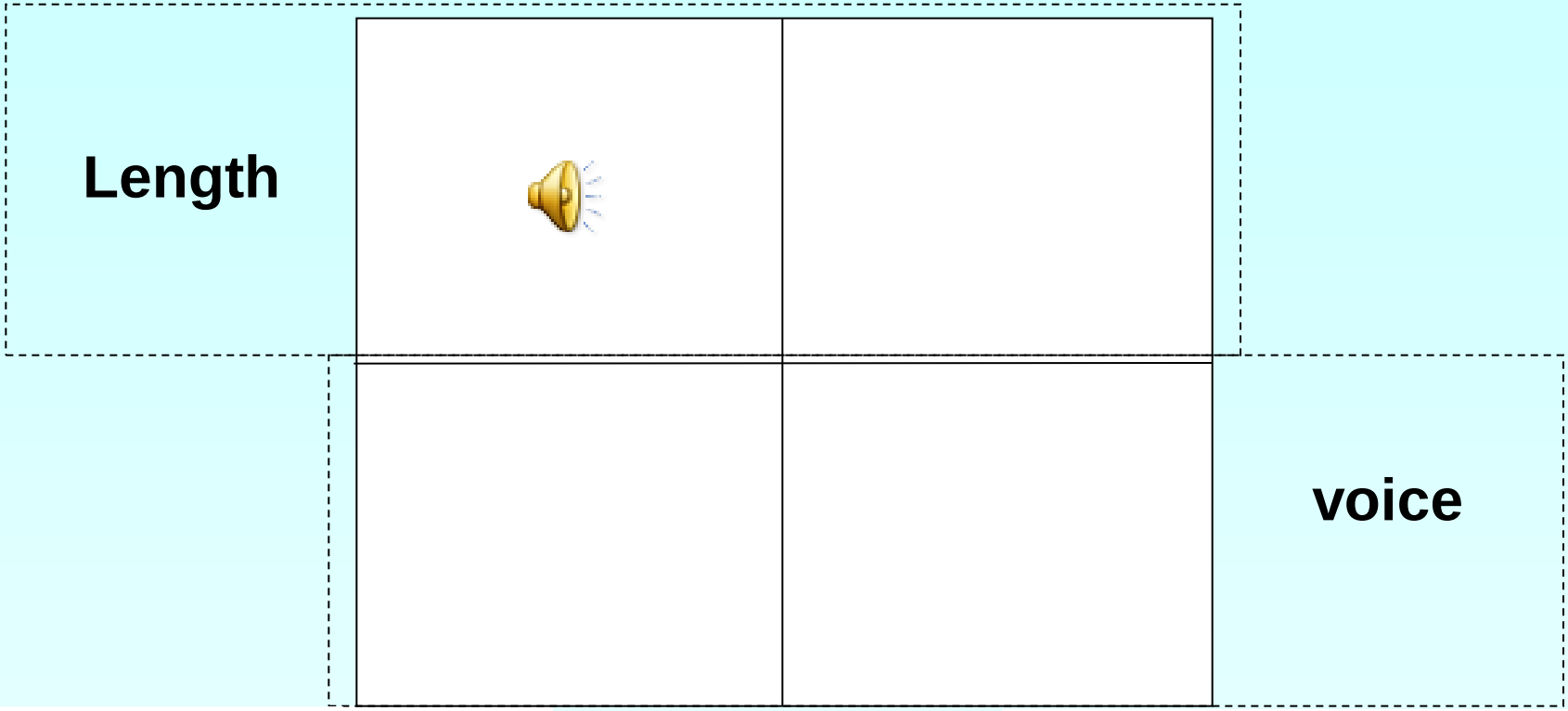
Task-switching paradigm (speech-based version)



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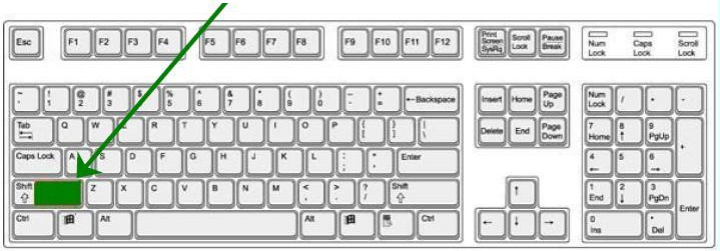

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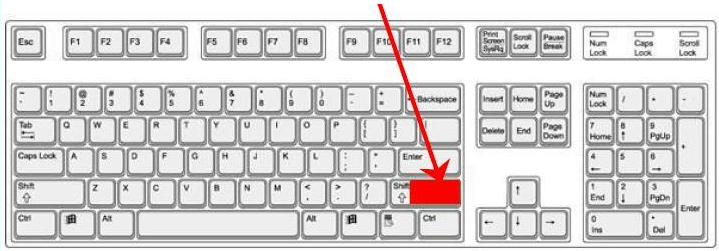

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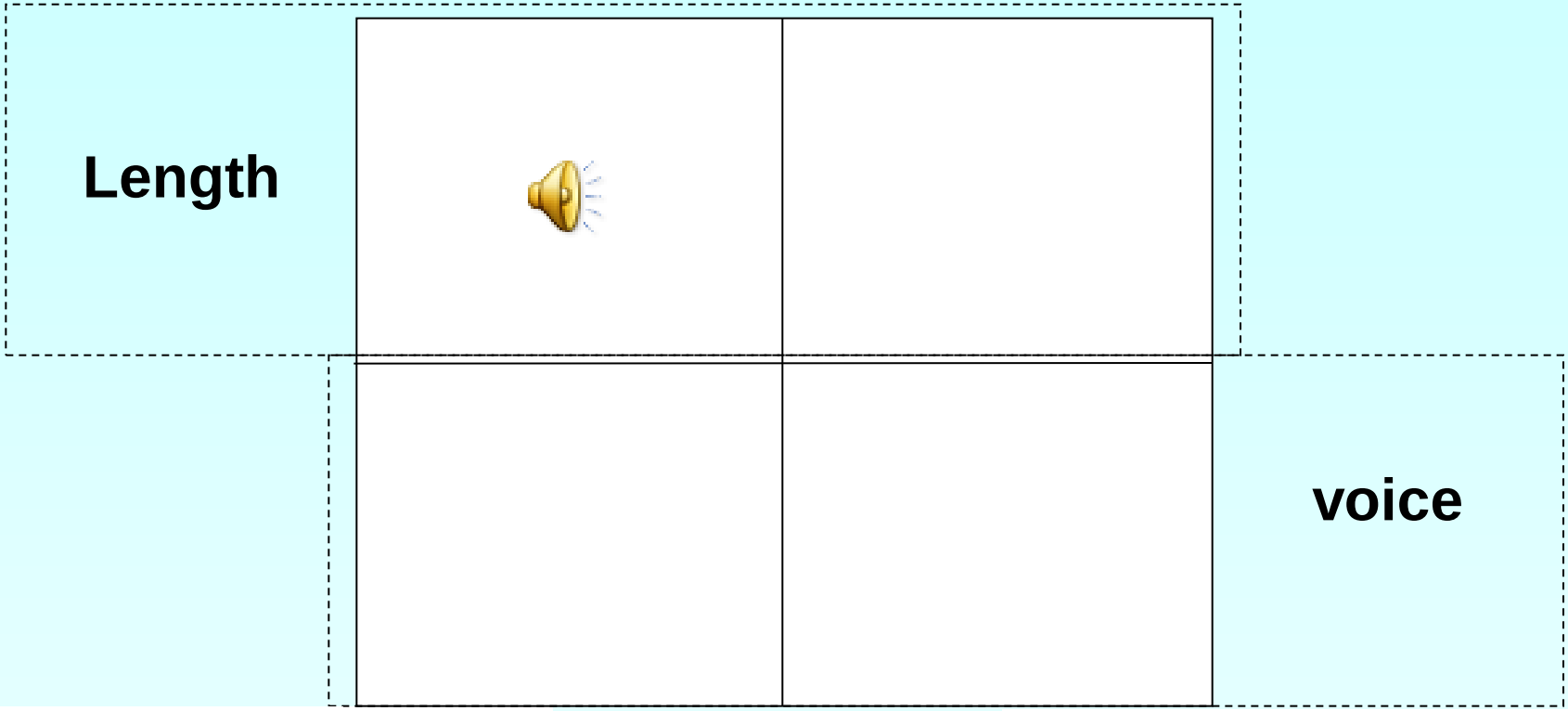

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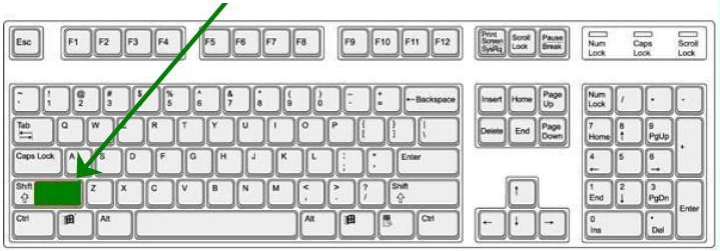

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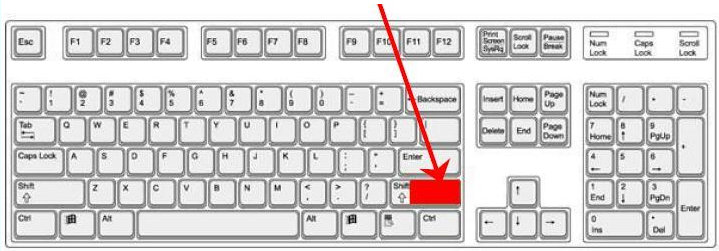

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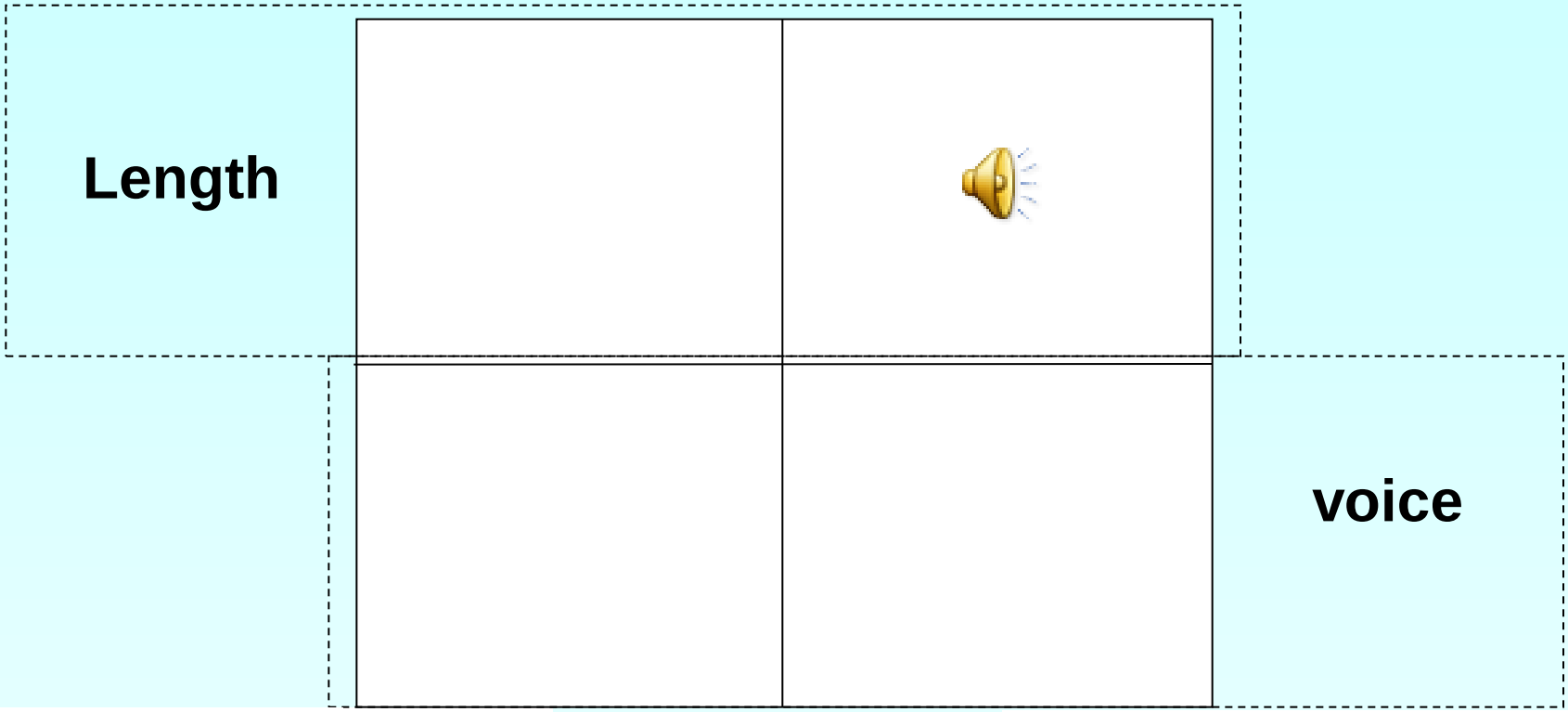

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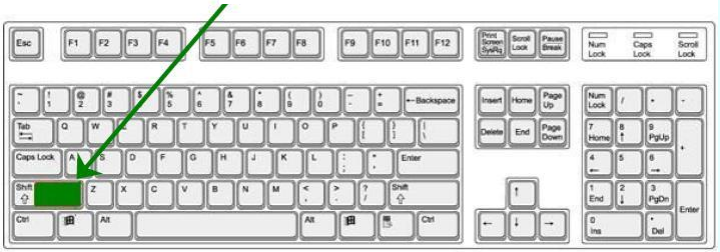

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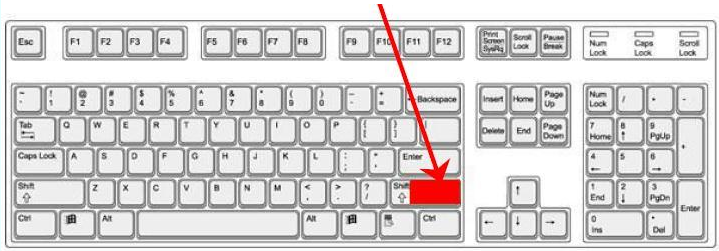

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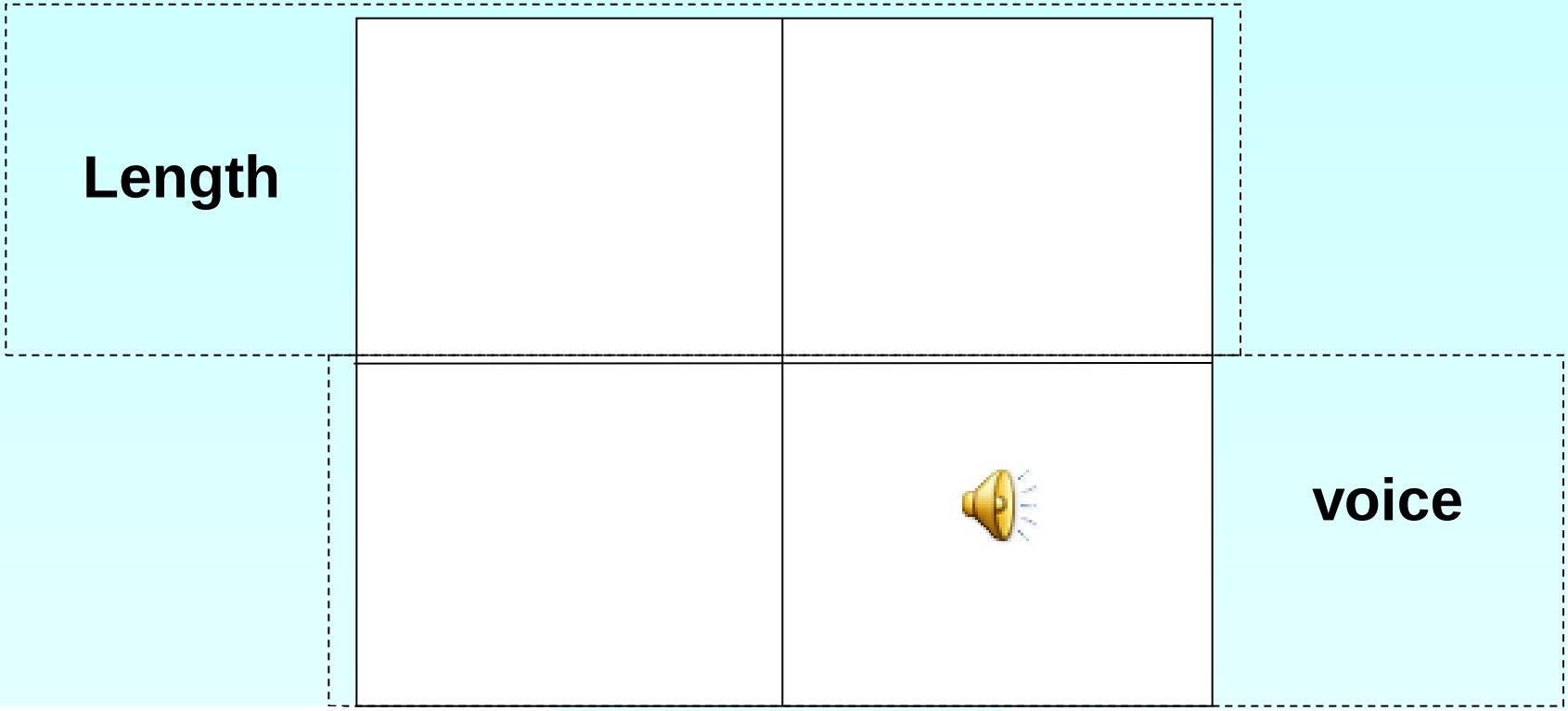
Task-switching paradigm (speech-based version)



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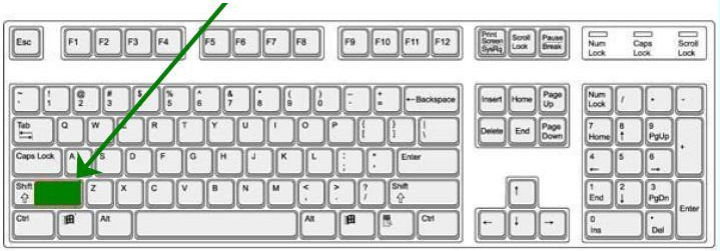

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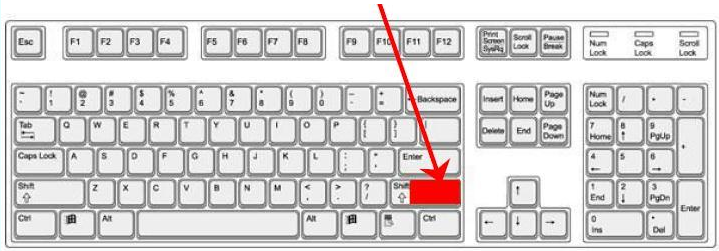

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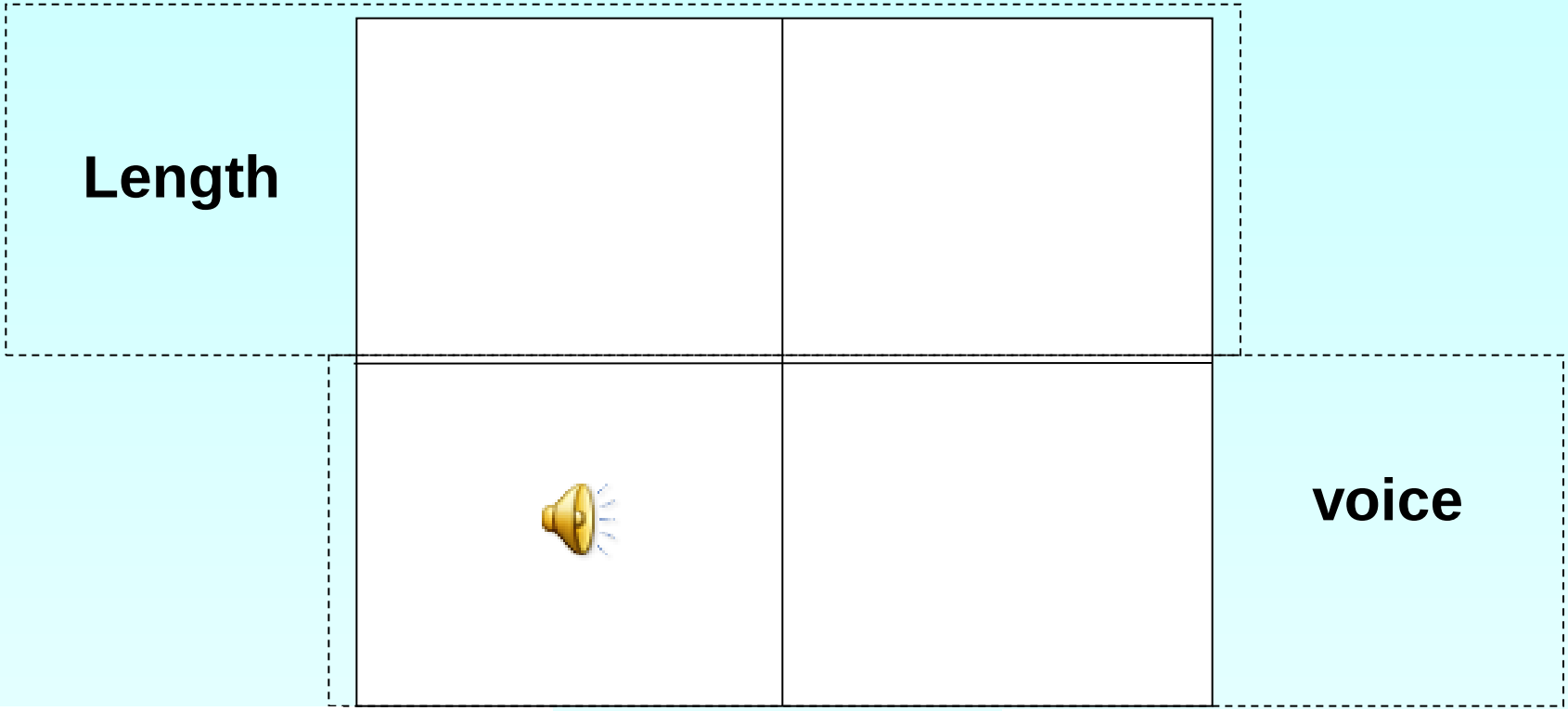
Task-switching paradigm (speech-based version)



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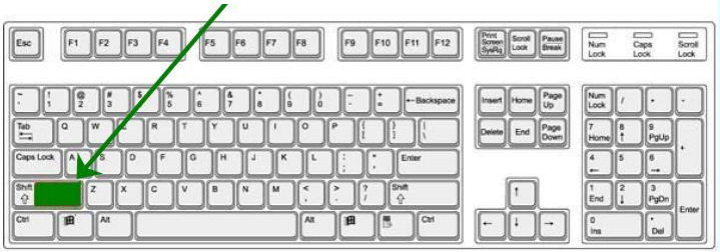

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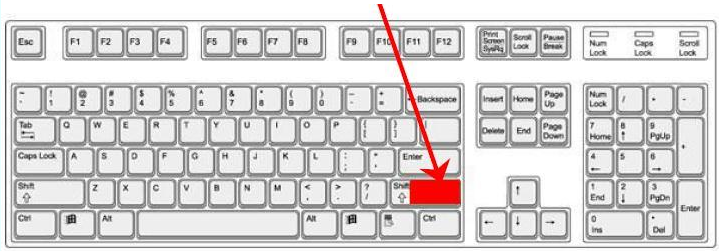
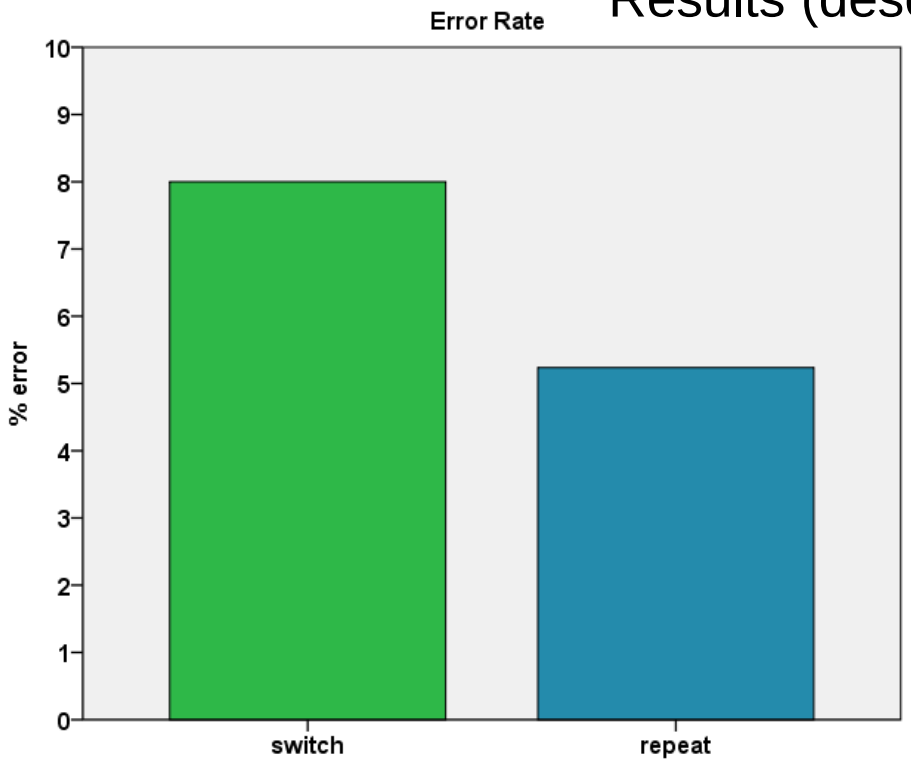
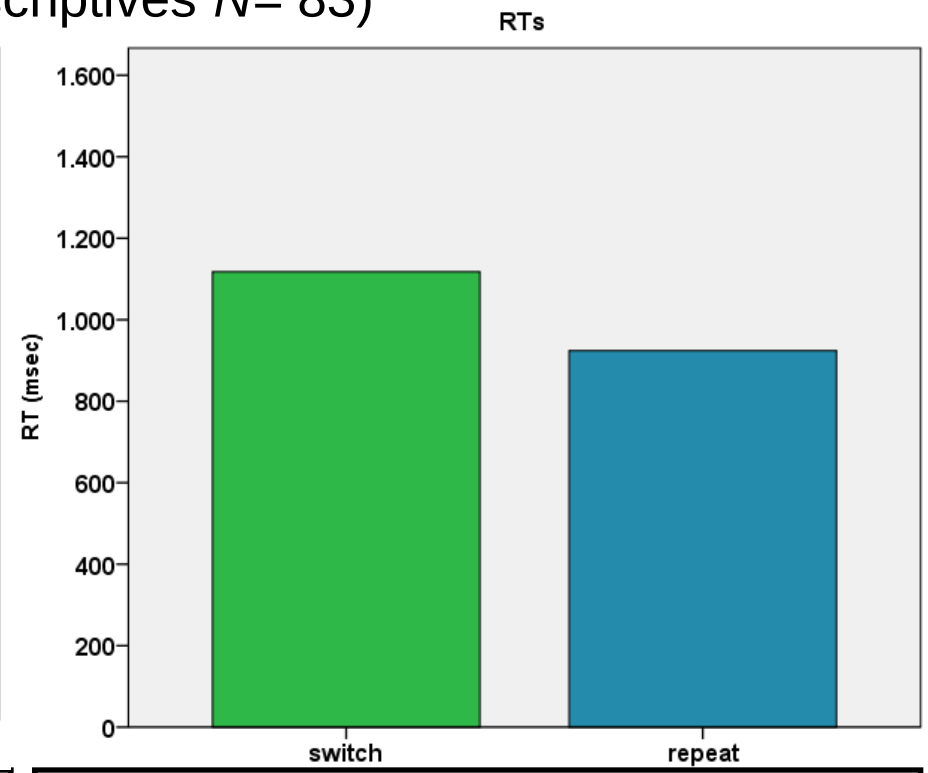


Attention Control (AC)

Results (descriptives *N*= 83)





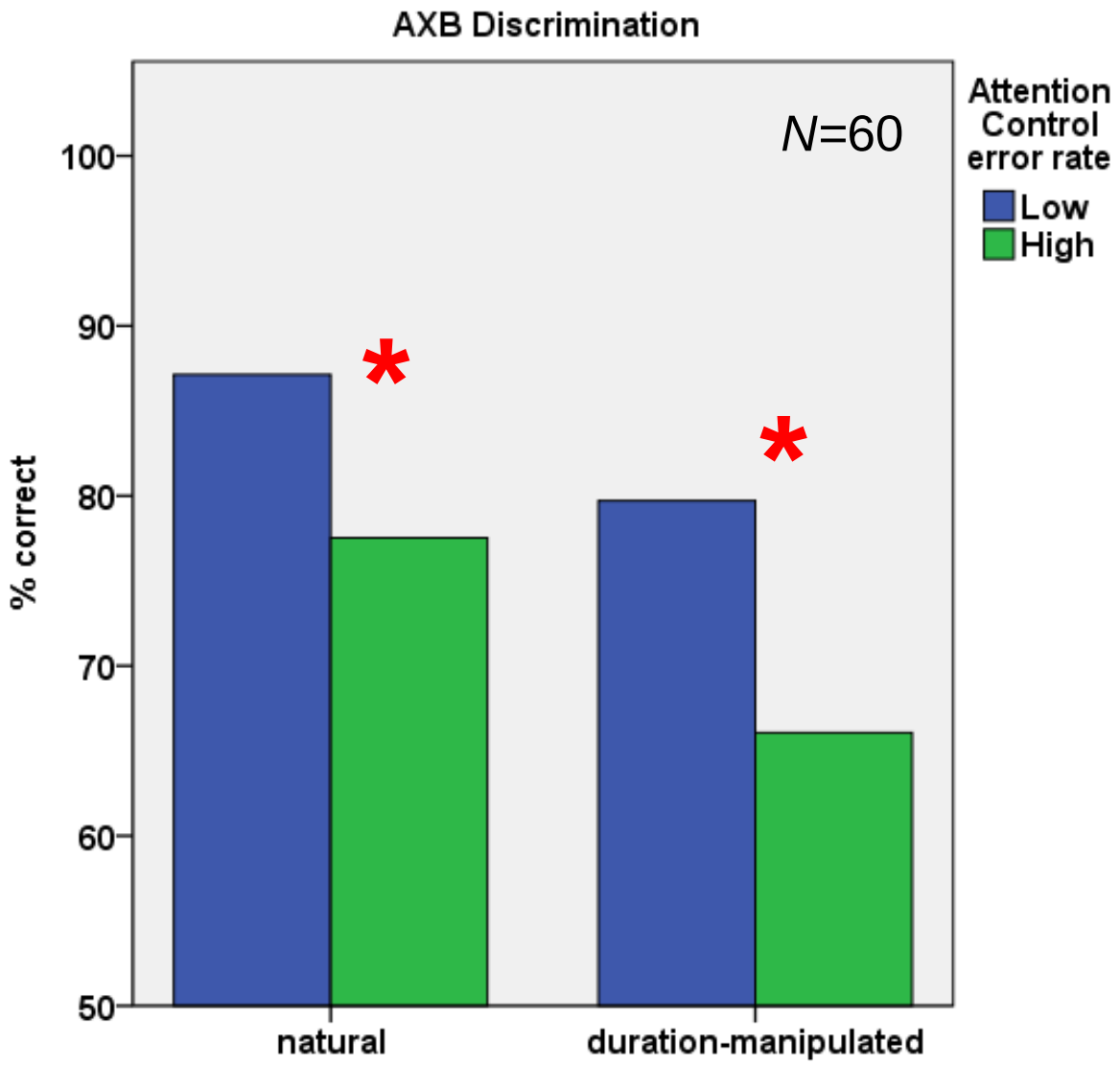
Error Rate (% ER)
Switch trials = 8.00
Repeat trials = 5.23

RTs

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

(Safronova & Mora, 2013)

Attention Control (AC)



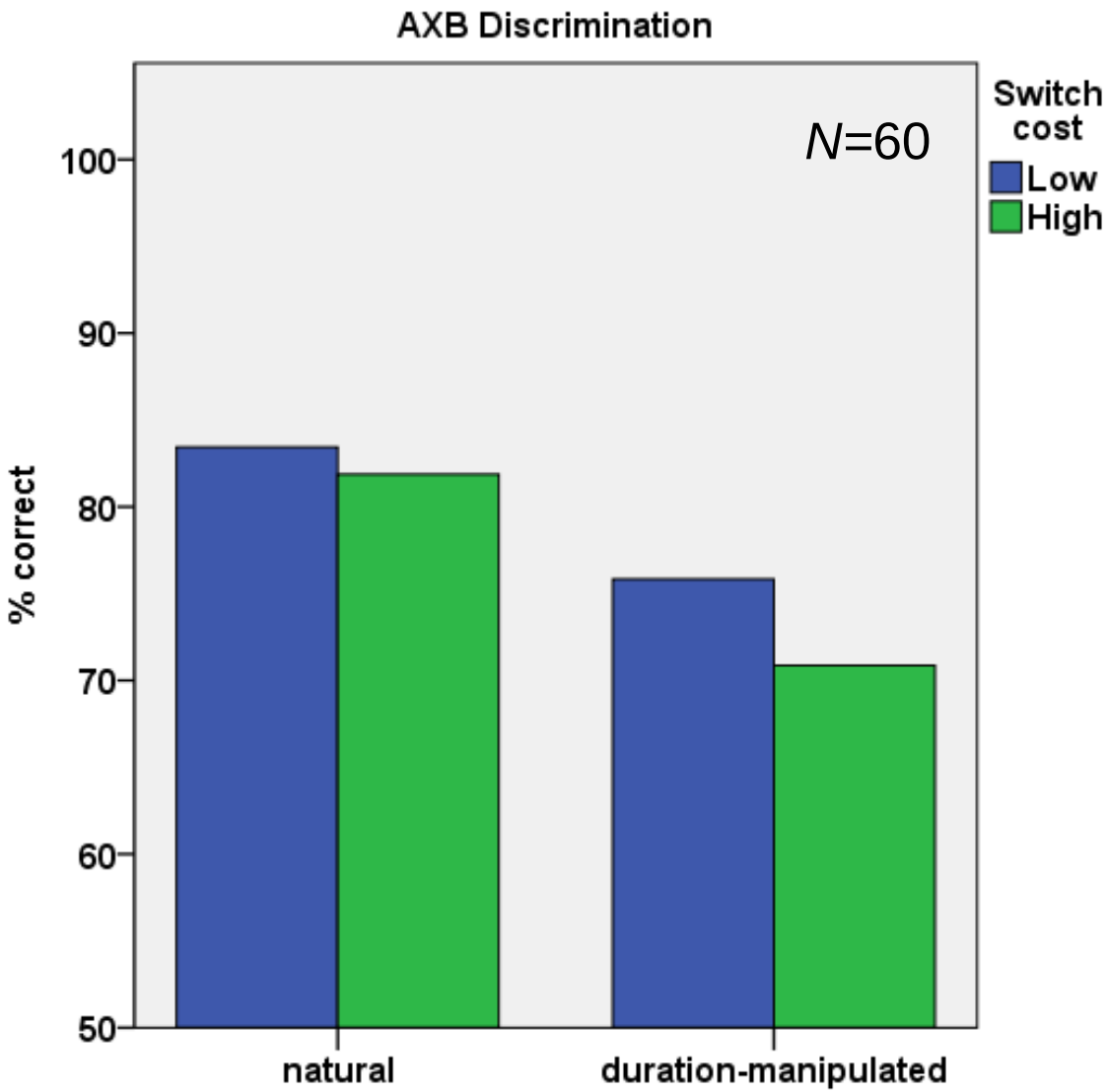
Pearson r	AC ER
DIS Nat	-.431**
DIS Man	-.476**

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)

Attention Control (AC)



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)

Darcy, Mora & Daidone (2013)

- Attention Control
- Inhibition

→

- L2 production
- L2 perception

Spain	United States
• 35 L2 learners of English • 10 native speakers – Universidad de Sevilla (Spain)	• 26 L2 learners of Spanish • 9 native speakers – Indiana University (Bloomington, USA)

Darcy, Mora & Daidone (2013)

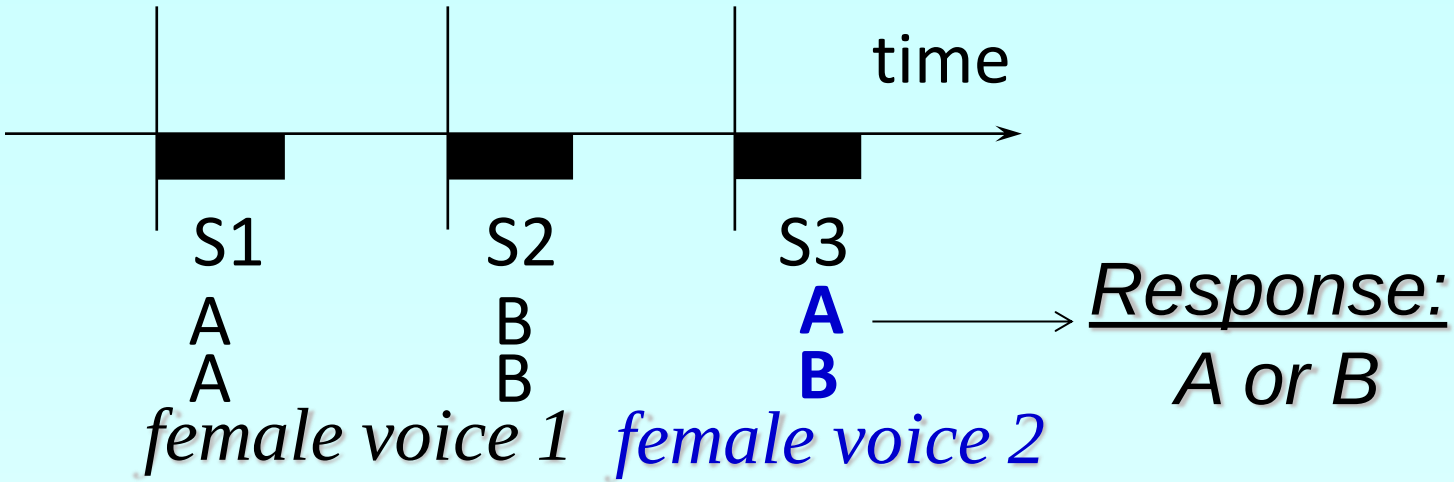
- Attention Control
- Inhibition

→

- L2 production
- L2 perception

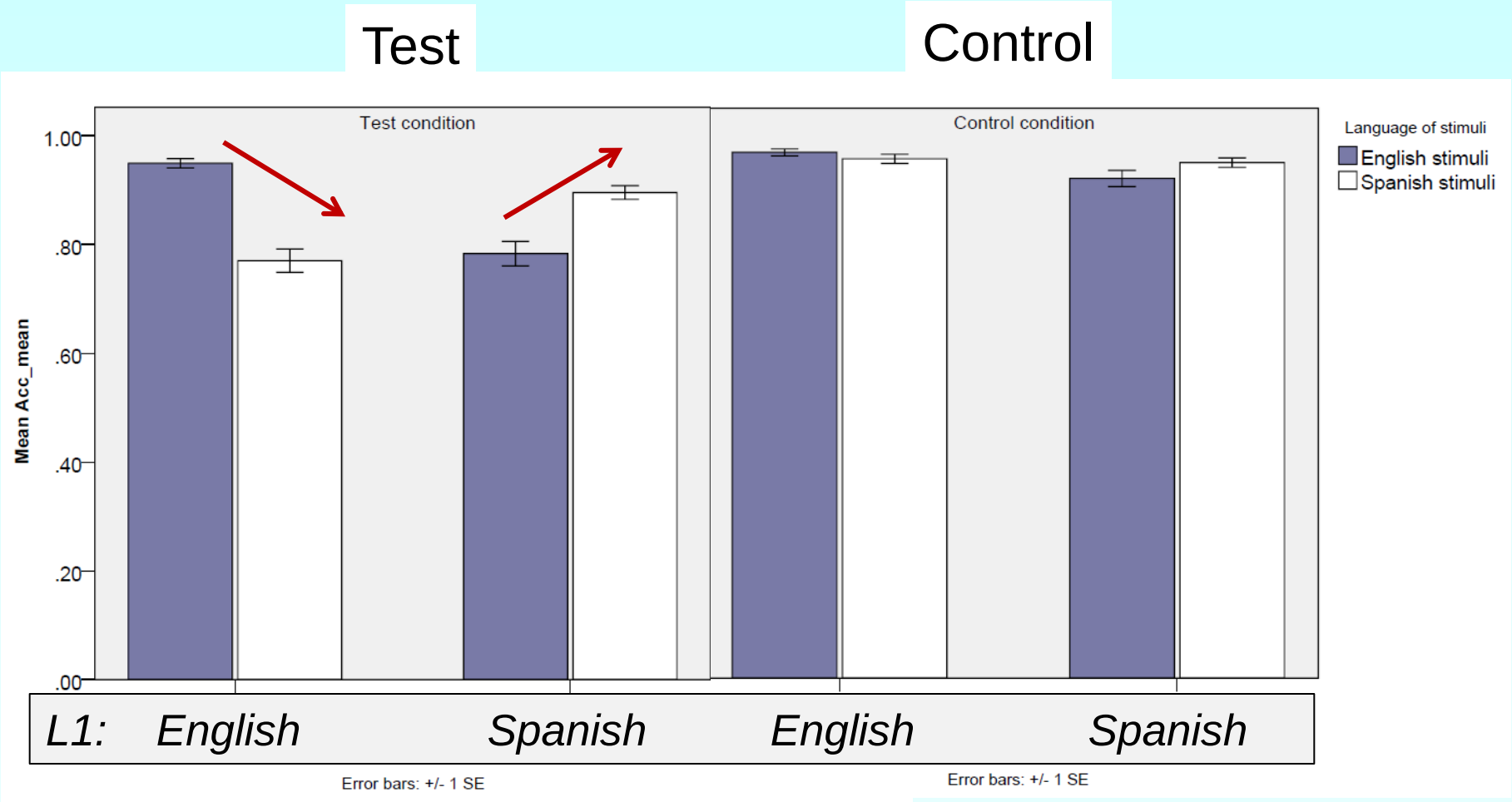
Spain	United States
• 35 L2 learners of English • 10 native speakers – Universidad de Sevilla (Spain)	• 26 L2 learners of Spanish • 9 native speakers – Indiana University (Bloomington, USA)

Perception: speeded categorial ABX task



Stimulus	item A	item B	Condition
Spanish	**saˈɾeβo**	**saˈðeβo**	Test C
English	**səˈʃiːdən**	**səˈtʃiːdən**	Test C
Spanish	**faˈneða**	**faˈneɪða**	Test V
English	**fəˈniːdɪʃ**	**fəˈnɪdɪʃ**	Test V
Spanish	**gaˈtaso**	**gaˈðaso**	Control C
English	**gəˈtæfɪn**	**gəˈdæfɪn**	Control C
Spanish	**luˈpito**	**luˈpato**	Control V
English	**ləˈpiːdɪk**	**ləˈpædɪk**	Control V

Perception results: speeded categorial ABX task



Attention Control (AC)

Switch-Repeat alternation of stimuli

- Attention switching between acoustic dimensions: Nasality vs. Native language phonetics

- 2 stimuli sets (Spanish & Am.English)

- 2 native bilinguals recorded 2 stimuli sets.

Spanish Nasal	English Nasal
ˈnoma	ˈnoʊmə
ˈnole	ˈnoʊleɪ
ˈniso	ˈnɪsoʊ
Spanish Nonnasal	**English Nonnasal**
ˈpiɣo	ˈpɪgoʊ
ˈdofe	ˈdoʊfeɪ
ˈsaso	ˈsæsoʊ

Attention Control (AC)

Question → Auditory stimulus → Response

Example: L1-English learner of L2-Spanish

English?

YES

NO

Attention Control (AC)

Question → Auditory stimulus → Response

Example: L1-English learner of L2-Spanish

English?

YES

NO

Attention Control (AC)

Question → Auditory stimulus → Response

Example: L1-English learner of L2-Spanish

Nasal?

YES

NO

Attention Control (AC)

Question → Auditory stimulus → Response

Example: L1-English learner of L2-Spanish

Nasal?

YES

NO

Attention Control (AC)

Question		Auditory stimulus	Response
English?	R	['doʊfeɪ]	YES
English?	S	['noma]	NO
Nasal?		['sæsoʊ]	NO
Nasal?	R	['niso]	YES

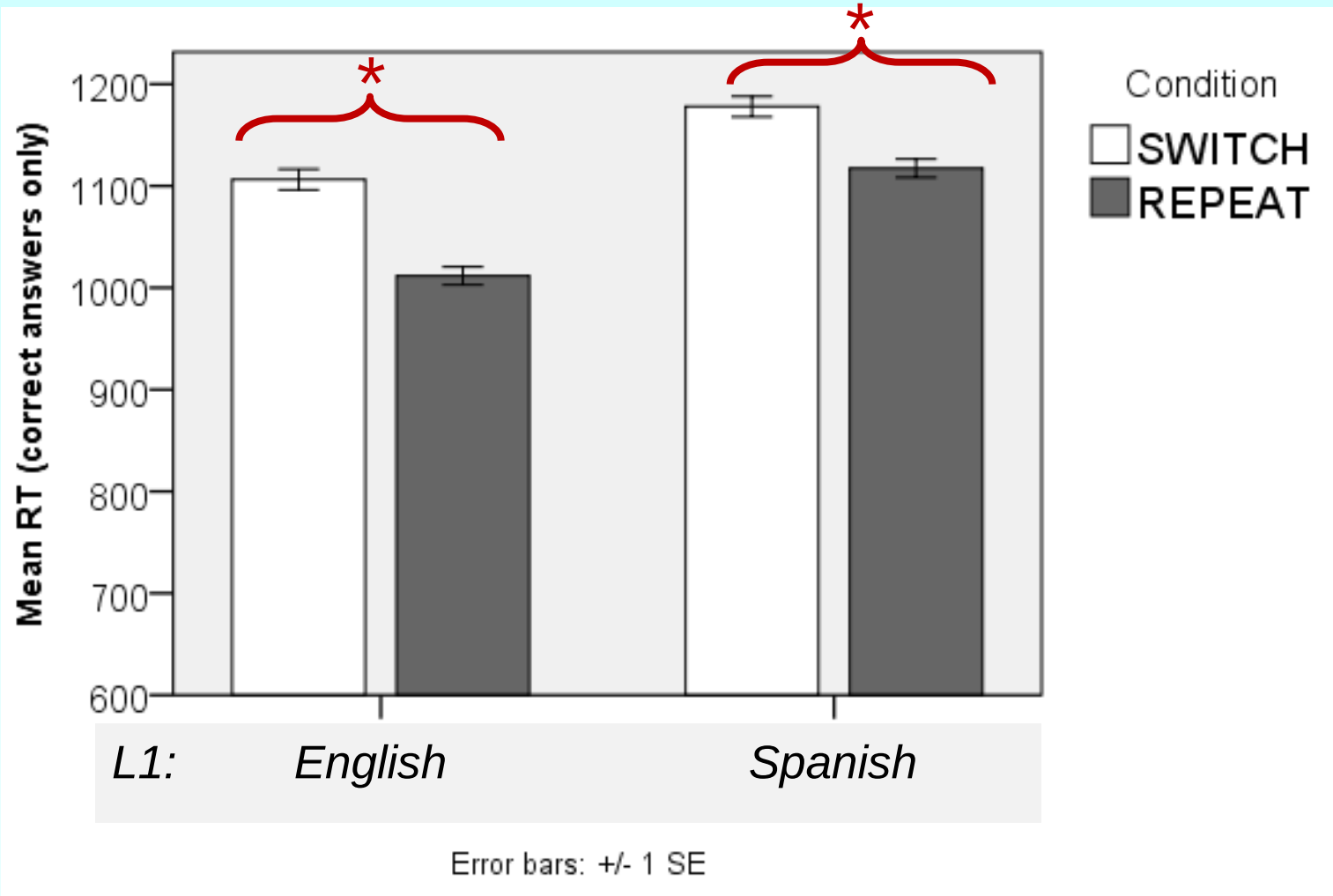
Measures:

RT on **Switch** vs. **Repeat** (baseline) conditions

Switch cost: **Switch** – **Repeat**, for each participant

Attention Control (AC)

Results:



Attention Control (AC)

Vocabulary test score
used as covariate to partial out proficiency

- Attention Control ⟷ **- L2 perception**

	Perception (ABX)	
Attention (shift cost)	L2 Sp	***n.s.***
	L2 En	***r*= -.488***

Inhibition

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.

Inhibition in language and speech:

- **Bilingual language control: e.g. L1/L2**
  - **Inhibition of the language not in use**
- **Lexical selection in word retrieval processes**
  - **inhibition as the suppression of activation: higher inhibition > harder to activate (harder to overcome suppression)**
- **Cue-weighting in L1/L2 speech processing**
  - **Focusing attention on a cue inhibits another:**

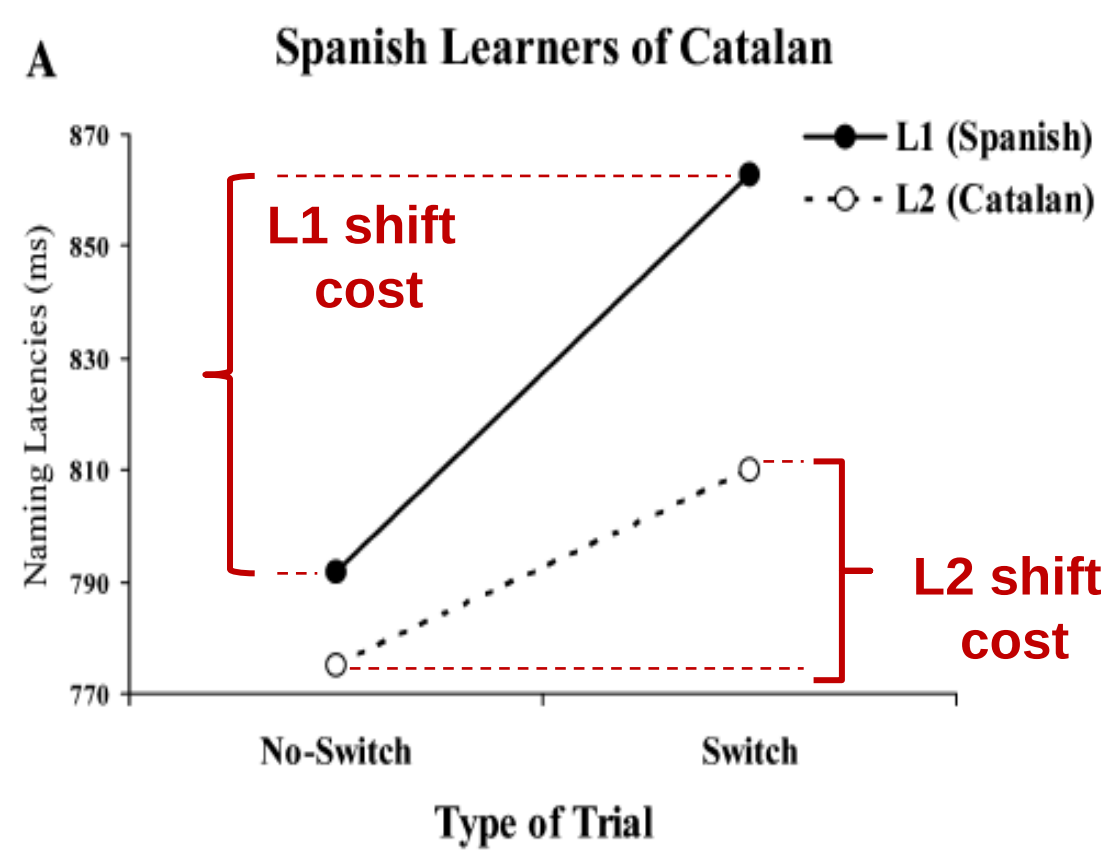
    e.g. V Duration is inhibited when processing V quality

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

Inhibition

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 slower in Switch than Nonswitch trials.**

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

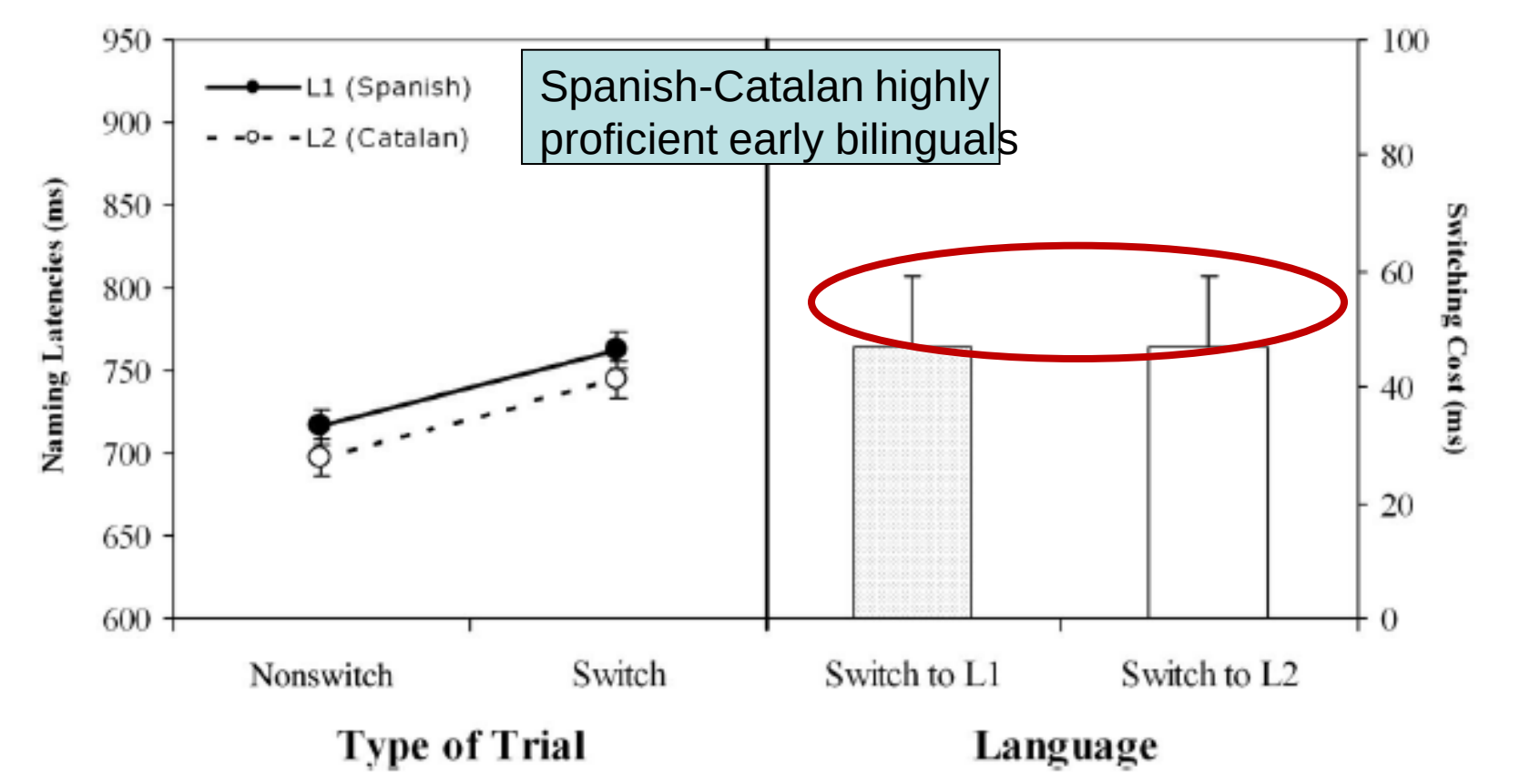
  > shifting to L1 requires more time (to overcome inhibition)

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

Inhibition

Amount of inhibition = Level of proficiency

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



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

Inhibition

Inhibition and L2 phonological acquisition

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

> Learners with better inhibitory control may be more efficient at inhibiting their L1 phonetics and phonology when speaking their L2

> more accurate, less foreign-accented speech

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

Inhibition: inhibitory control task

Memorize

- Vegetables
  - Lettuce
  - Potato
  - Artichoke
  - Onion
  - Spinach
  - Tomato
- Animals
  - Duck
  - Snake
  - Elephant
  - Horse
  - Tiger
  - Cow
- Occupations
  - Plumber
  - Teacher
  - Fireman
  - Carpenter
  - Engineer
  - Nurse

Practice

Type: Vegetable-L___

- Vegetables
  - Lettuce
  - Potato
  - Artichoke
  - Onion
  - Spinach
  - Tomato
- Animals
  - Duck
  - Snake
  - Elephant
  - Horse
  - Tiger
  - Cow
- Occupations
  - Plumber
  - Teacher
  - Fireman
  - Carpenter
  - Engineer
  - Nurse

Increased activation

Inhibited

Control (non practiced category)

Recognize

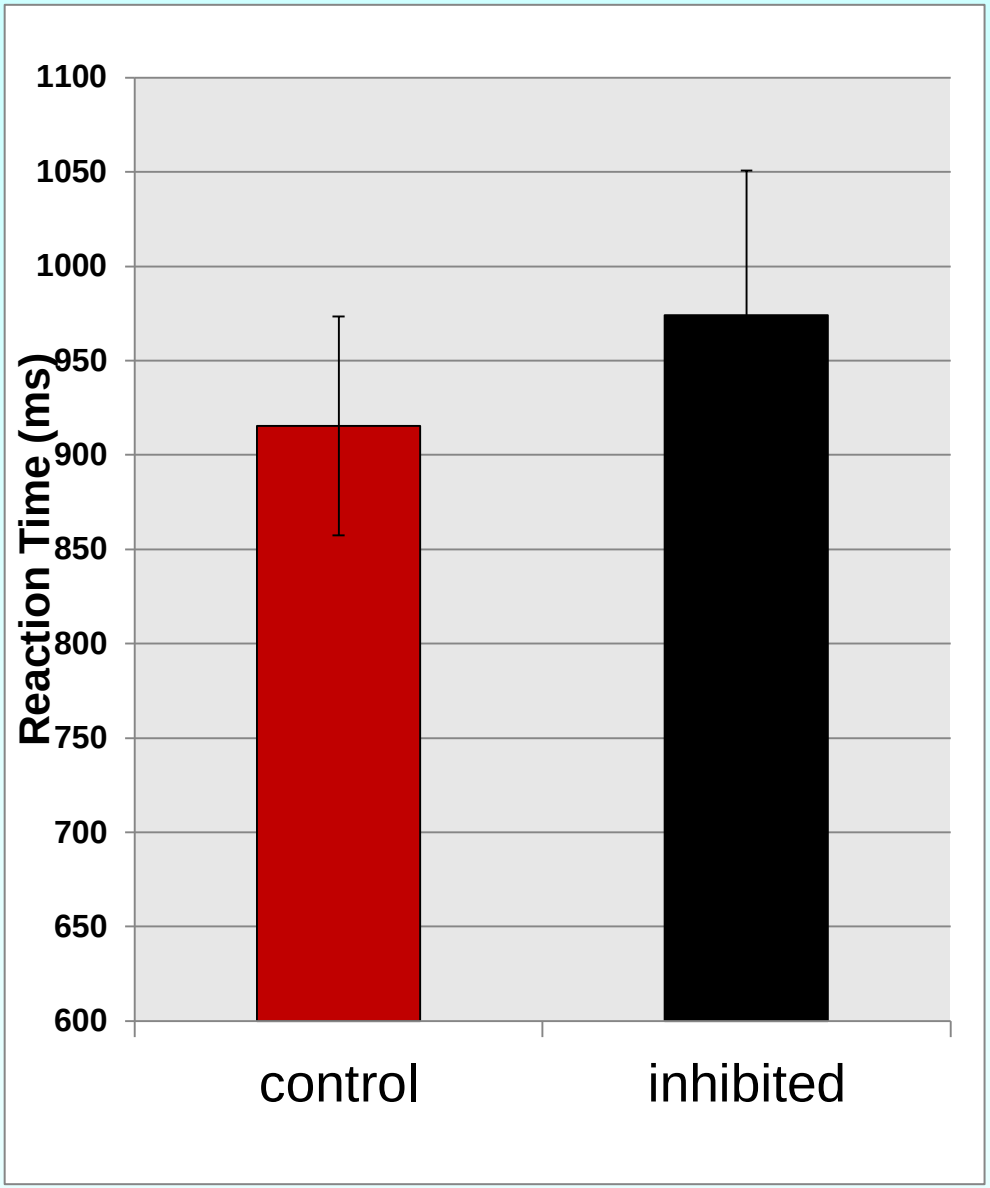
- Vegetables
  - Lettuce
  - Potato
  - Artichoke
  - **Onion**
  - **Spinach**
  - **Tomato**
- Animals
  - Duck
  - Snake
  - Elephant
  - **Horse**
  - **Tiger**
  - **Cow**
- Occupations
  - **Plumber**
  - **Teacher**
  - **Fireman**
  - **Carpenter**
  - **Engineer**
  - **Nurse**

PLUS additional items never presented before (e.g. secretary)

RT on inhibited / RT on control

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

Inhibition: results



(Proficiency partialled out)

- Inhibition

- ABX accuracy

	Perception (ABX)
Inhibition (score)	L2 Sp ***r*= .507*** L2 En ***r*= .615***

Cognitive skills and L2 speech perception

Cognitive skills → **L2 phonological competence**

Phonological short-term Memory (PM)

Acoustic Memory (AM)

Attention Control (AC)

INHIBITION (INH)

- Explain inter-learner variability
- Not all cognitive skills seem to have the same weight, but:
  - variety of cognitive tasks
  - variety of L2 phonological assessment tasks
- L2-Learner populations may differ in crucial respects. e.g. we recently found a much weaker relationship between Inhibitory control and ABX discrimination with a bilingual population in Barcelona.

PM, AM, AC & L2 Vowel Perception

Regression Analyses (*N*=60)

R^2=.286 (28.6%); *p*=.001 (Nat)

R^2=.285 (28.5%); *p*=.001 (Man)

	% Unique Variance Explained	*p*=	
Phonological short-term Memory (PM)	0.01	.945	Nat
	0.03	.881	Man
Acoustic Memory (AM)	11.3	.007	Nat
	4.9	.070	Man
Attention Control (AC ER)	3.5	.123	Nat
	9.5	.013	Man

AXB discrimination /iː/-/ɪ/

PM, AM, AC & L2 Vowel Perception

Regression Analyses

R^2=.258 (25.8%); *p*=.002 (Nat)

R^2=.236 (23.6%); *p*=.004 (Man)

	% Unique Variance Explained	*p*=	
Phonological short-term Memory (PM)	0.23	.696	Nat
	0.55	.552	Man
Acoustic Memory (AM)	20.4	.001	Nat
	14.6	.003	Man
Attention Control (AC SC)	0.7	.510	Nat
	4.5	.092	Man

AXB discrimination /iː/-/ɪ/

Next steps

- Improving the speech-based tasks to measure cognitive skills. > current PhD work on phonological memory by Eva Cerviño-Povedano

- Training and pedagogy:

  > What is the role of individual differences in cognitive skills on L2 perception and production gains obtained through phonetic training?

  > Can speech-related cognitve functions be trained efficiently for the benefit of L2 phonological development? How?

- What is the role of individual differences in cognitive skills on cross-language speech perception and the formation of L2 phonetic categories? > current PhD work by Elena Safronova.

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Comments/questions:

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Phonological short-term memory (PM)

(Mora & Cerviño-Povedano 2010)

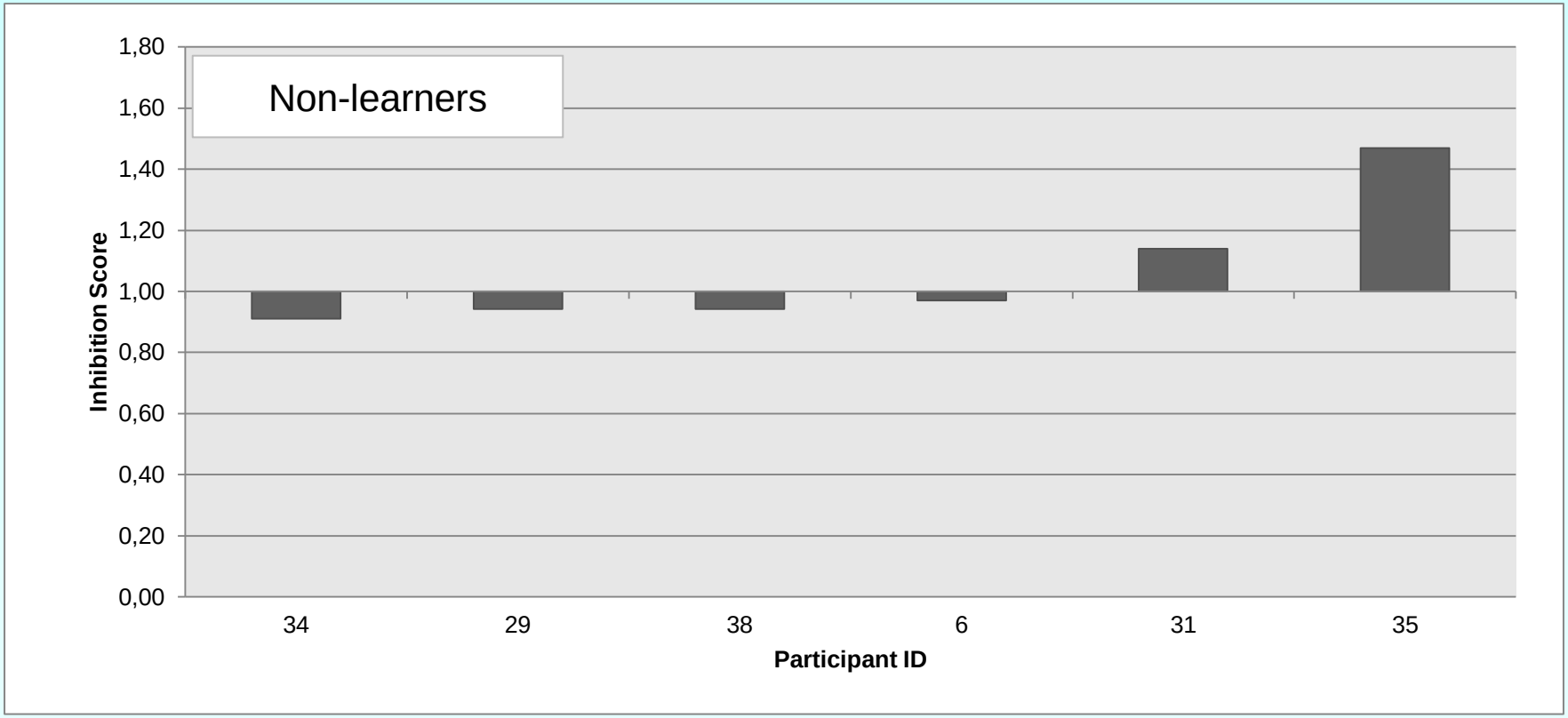
- 54 Catalan-Spanish Bilinguals
- ID (cue weighting): natural & duration manipulated MPs
- PM (SNWR): Catalan (L1), English (L2) and Russian (L0).
- PM score (median split) Low vs. High

Stimuli manipulation (Ylinen et al. 2010):
Tense /iː/ was given the duration of lax /ɪ/ (shortened) in every minimal pair produced by every speaker (and lax /ɪ/ → /iː/ tense (lengthened))

	Natural	Shortening/Lengthening	Manipulated
voiced	425ms /diːd/ 240ms /dɪd/	425ms → 240ms 240ms → 425ms	/diːd/ 240ms /dɪd/ 425ms
unvoiced	245ms /piːk/ 165ms /pɪk/	245ms → 165ms 165ms → 245ms	/piːk/ 165ms /pɪk/ 245ms

Inhibition: Results

- 1 means 2 RTs are the same
- higher bar = higher inhibition (higher RT in inhibited condition)



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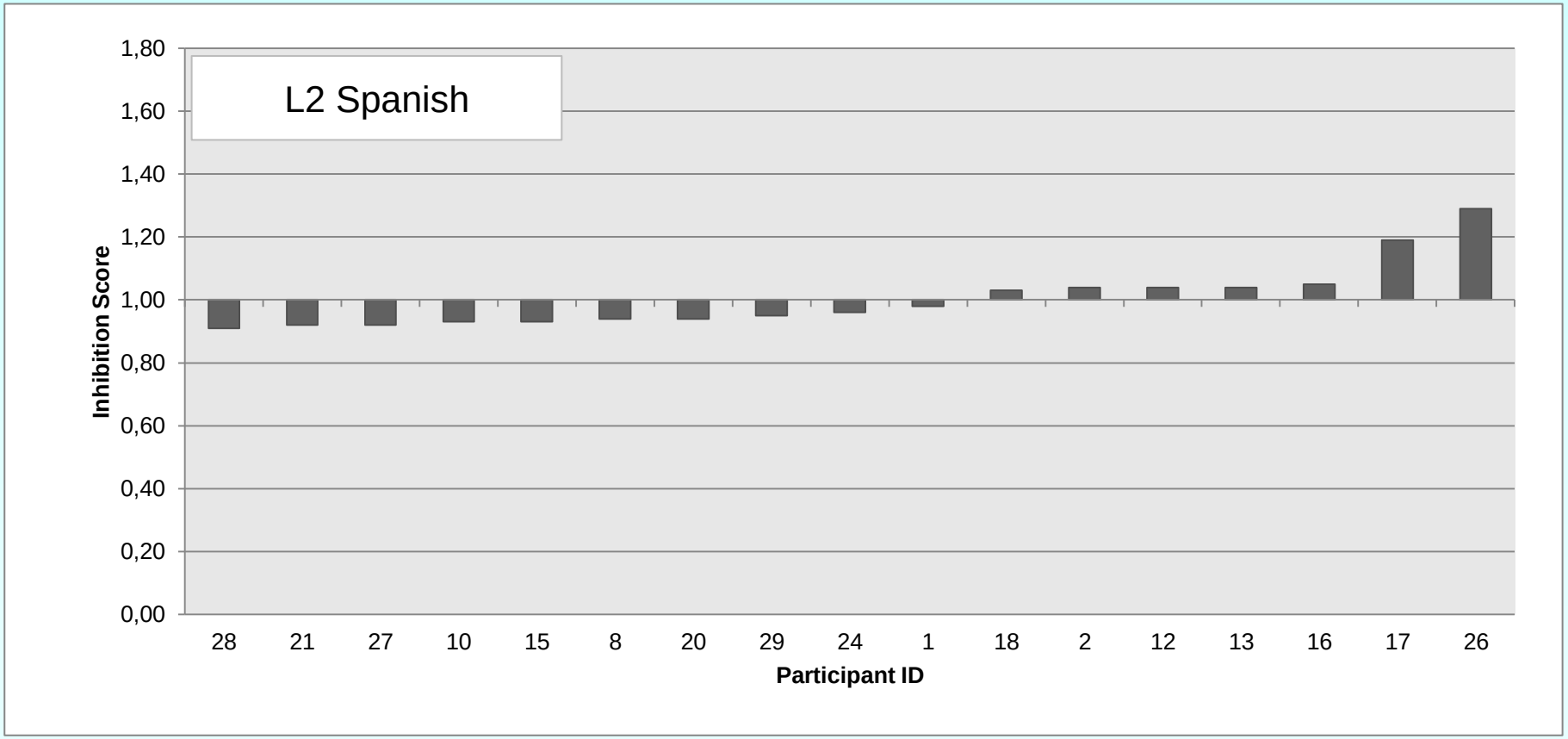

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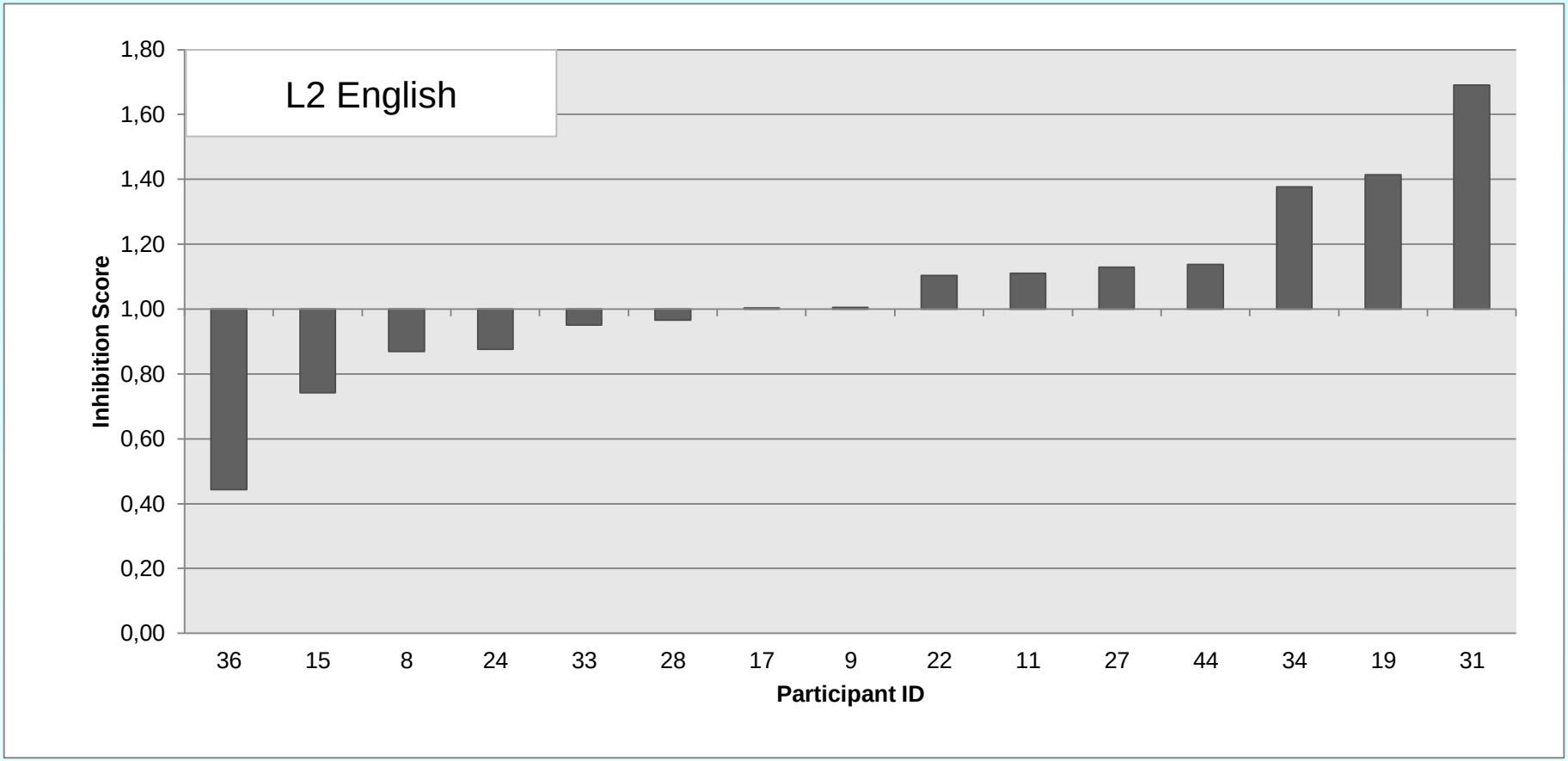


Inhibition

Amount of inhibition = Level of proficiency

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

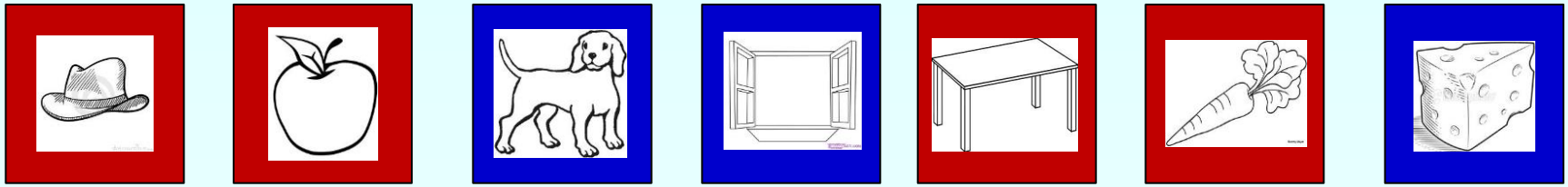
Language Switching Task (picture naming)

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

L1 L1 L2 L2 L1 L1 L2



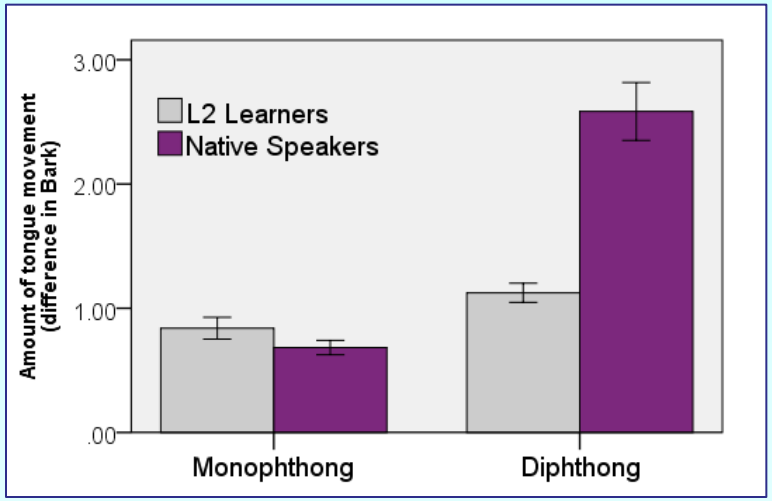
>non-s> >switch> >non-s> >switch> >non-s> >switch>

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

Production results: delayed sentence repetition

Spanish L2

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

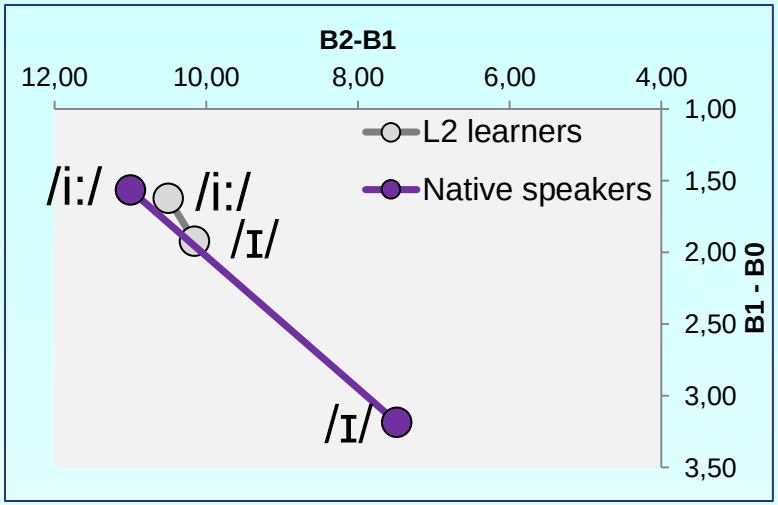


/ɾ/ - /ð/ Average score (max. 8)

L2 learners	Mean score	*SD*
n = 26	4.27	*2.20*
Native speakers (Spanish)		
n = 9	7.89	*0.3*

English L2

/iː/ - /ɪ/ : spectral differences (Bark)

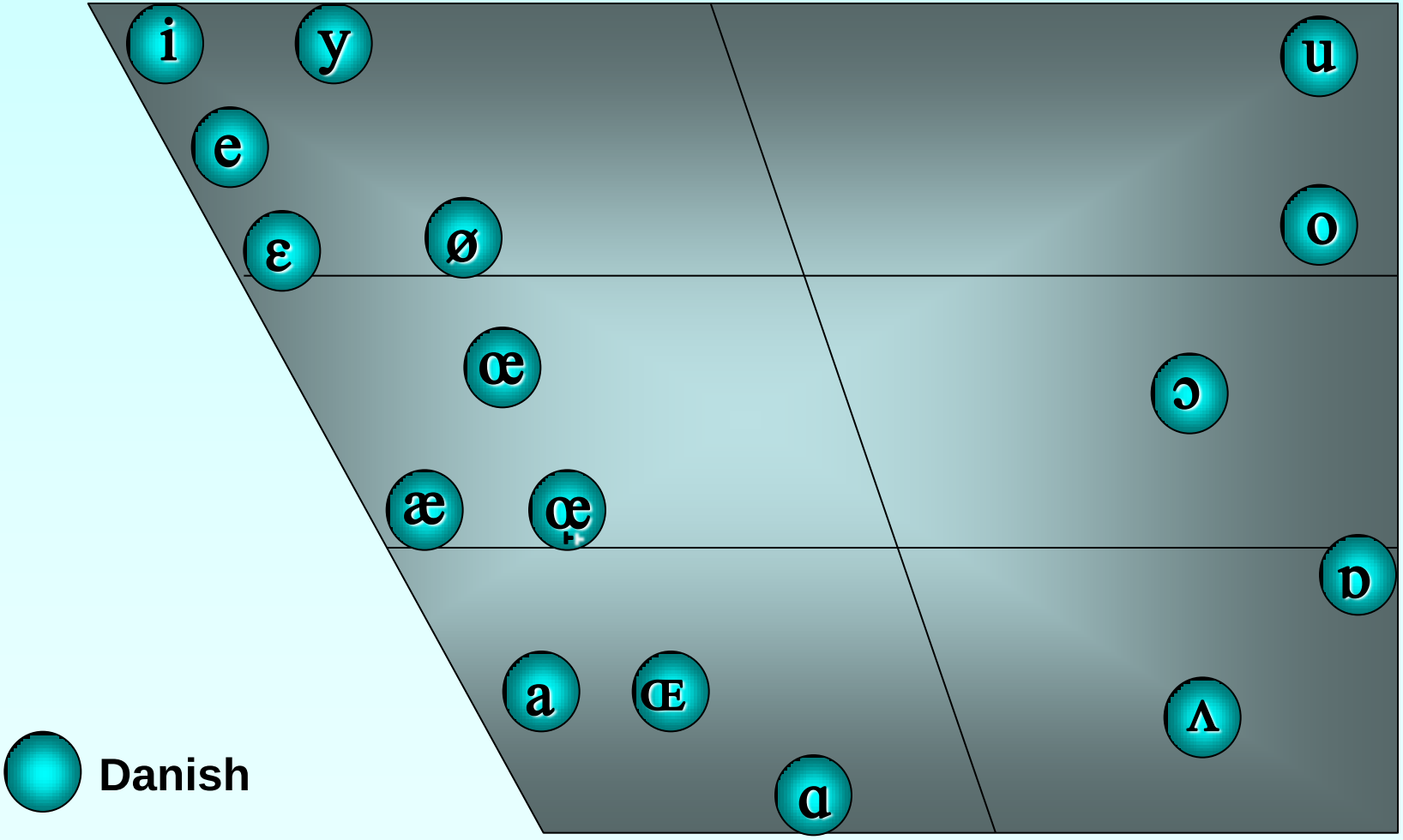


/ʃ/ - /tʃ/ Average score (max. 8)

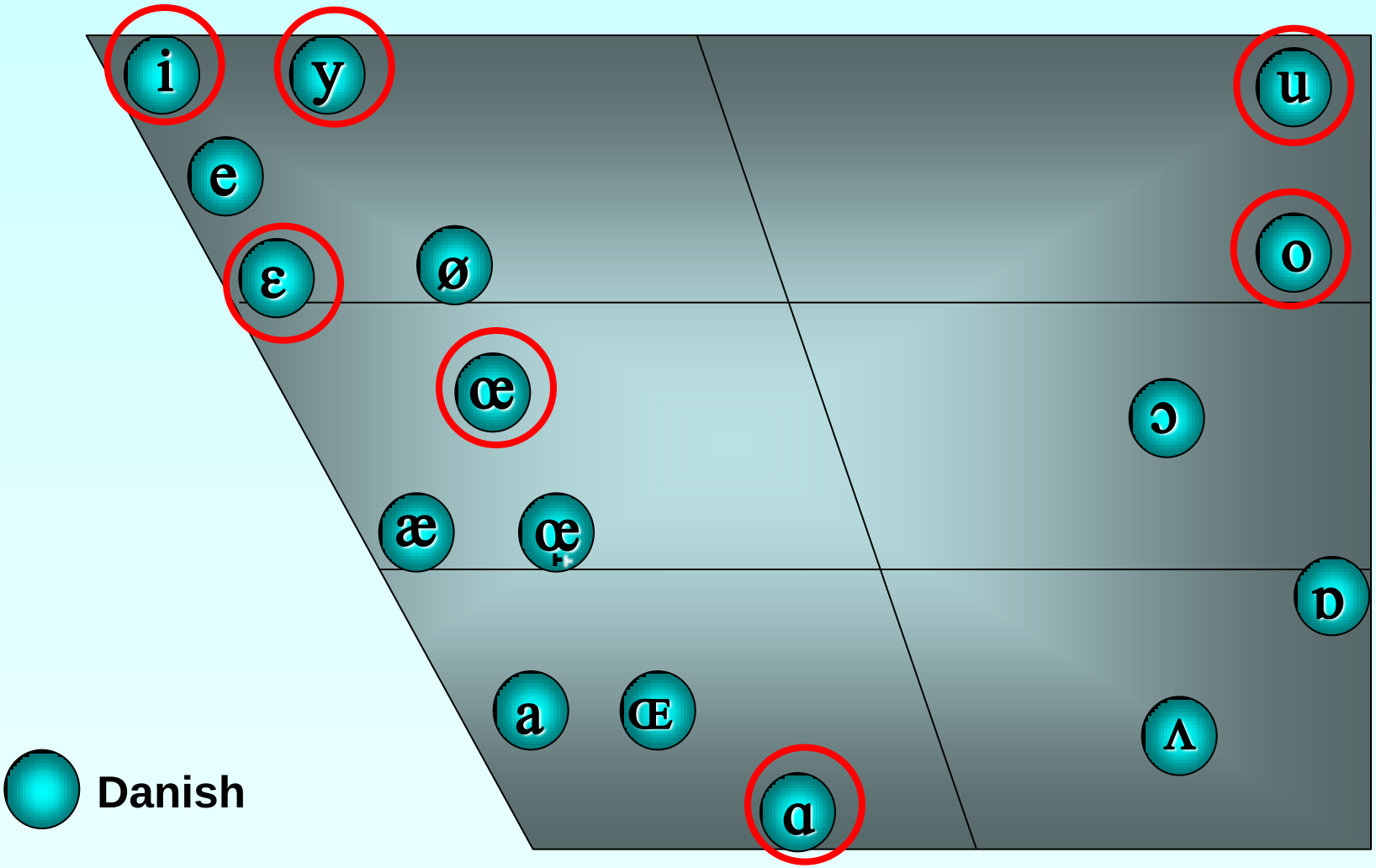
L2 learners	Mean score	*SD*
n = 35	6.89	*1.32*
Native speakers (English)		
n = 10	8	*0*

Phonological short-term memory (PM)

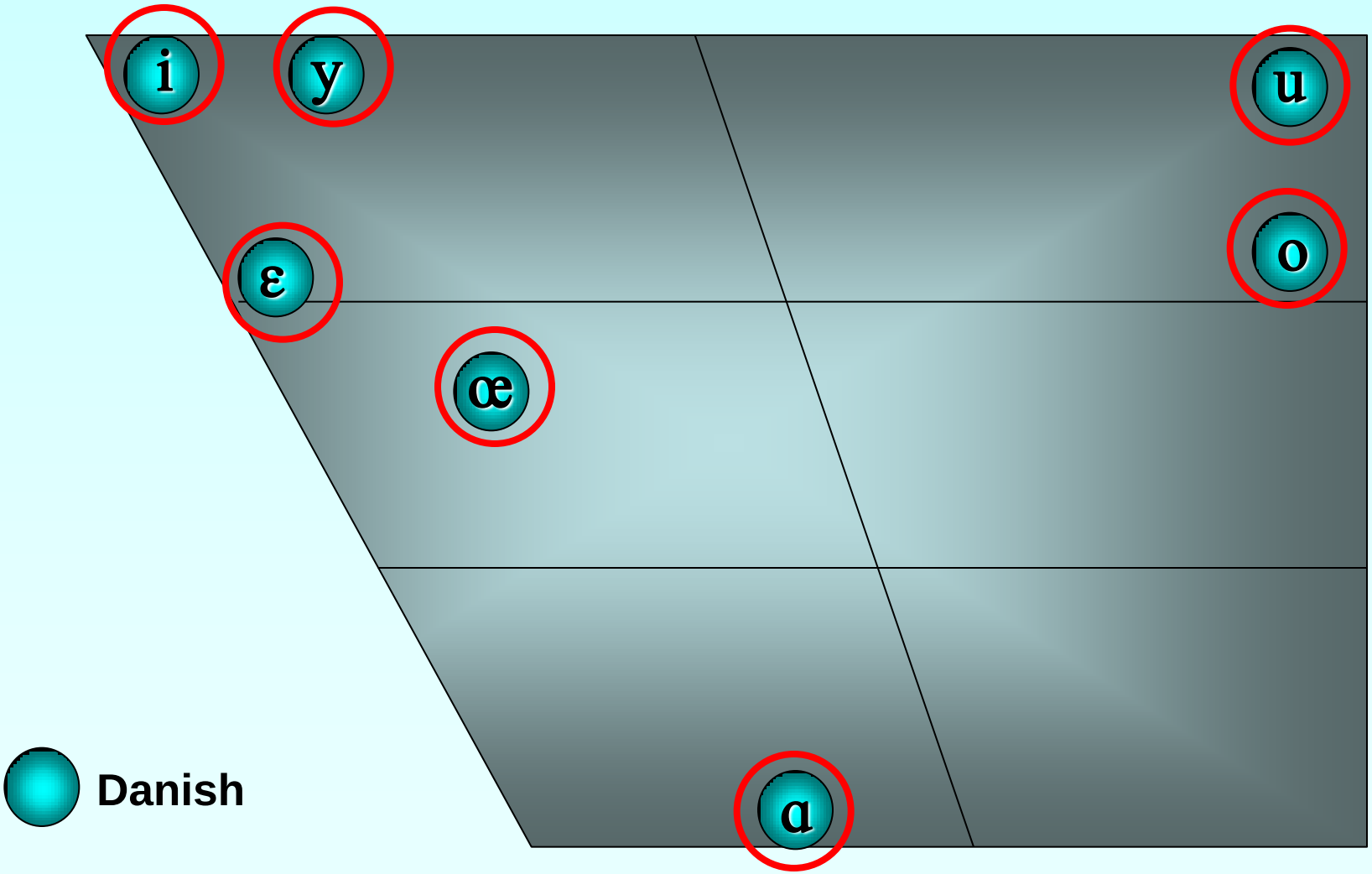
Danish



Phonological short-term memory (PM)



Phonological short-term memory (PM)



Phonological short-term memory (PM)