



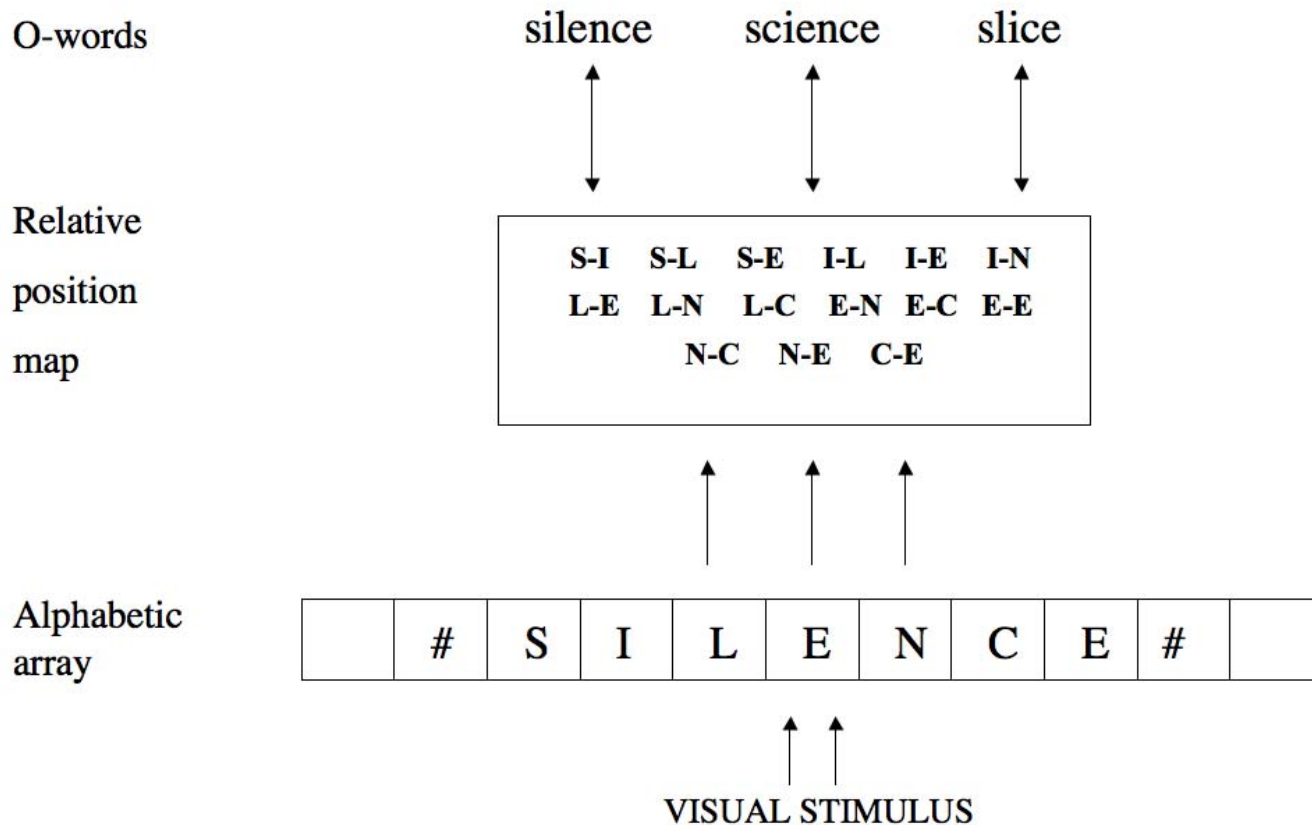
# Learning location invariant orthographic representations for printed words

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# Priming effects

- Robust priming effects in word recognition  
(see Grainger, 2008 for a review)
  - Transposed-letter priming: TALBE → TABLE
  - Relative-position priming: TBLE → TABLE
- Assuming that low-level visual stimuli are location-specific (retinotopic), how does the cognitive system develop flexible (location-independent) orthographic representations?

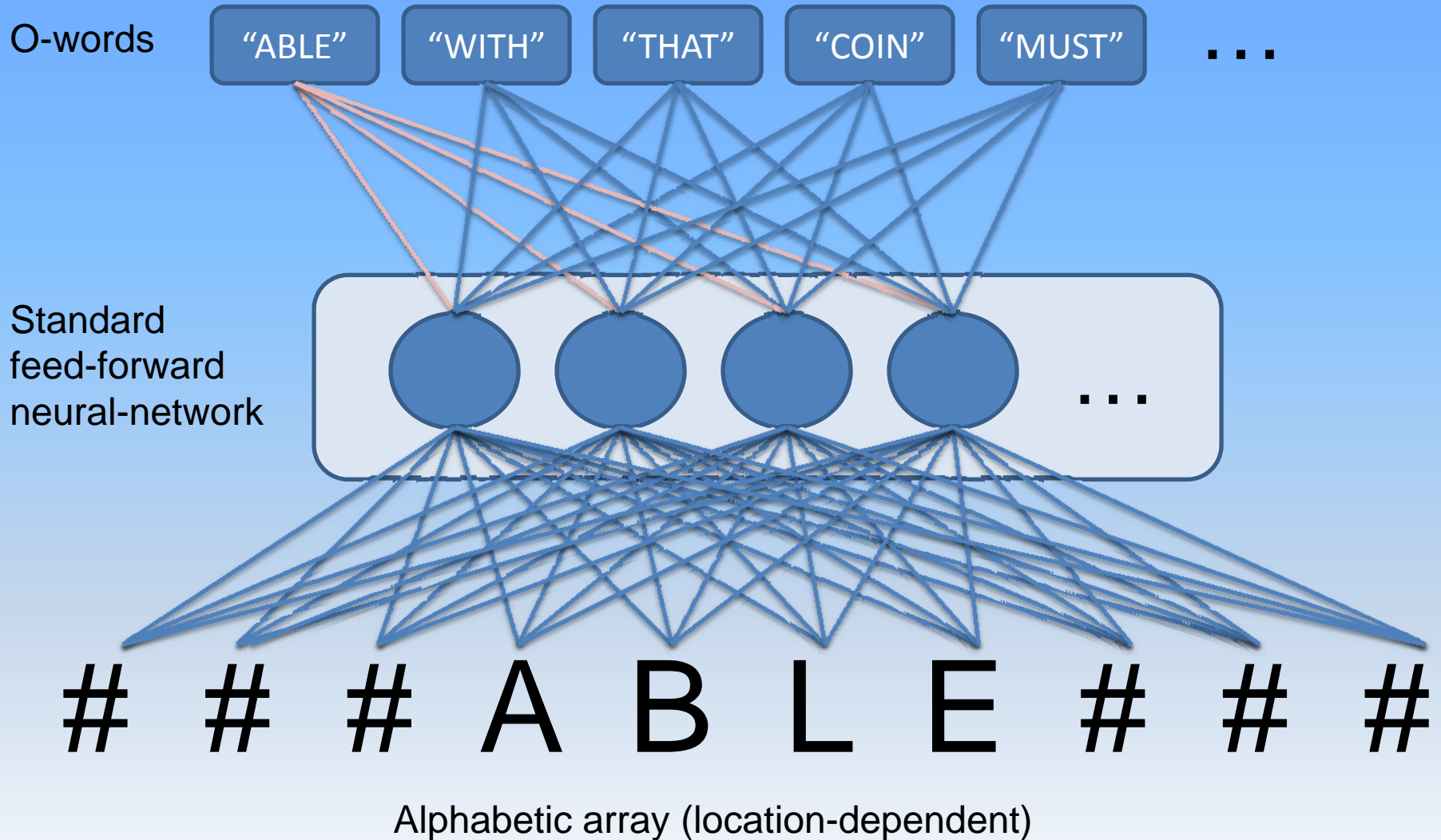
# Grainger and van Heuven's (2003) model of orthographic processing



# Location-invariant code

- Descriptive models:
  - Wickelcoding (Wickelgren, 1969)
  - Open-bigram coding (Grainger & van Heuven, 2003)
  - SERIOL (Whitney, 2001; Whitney & Berndt, 1999)
  - Spatial Coding (Davis 1999, 2006)
- Hypothesis: Uncertainty about letter positions
  - Overlap model (Gomez, Ratcliff and Perea, 2008)

# Computational model



# Research questions

- Do flexible orthographic representations (relative position map) naturally emerge in networks?
  - Transposed-letter priming
  - Relative-position priming
- Investigate the context of these effects
  - Emerge when words are presented at a single location vs. many locations?
  - Sensitive to the importance of letter order in the input lexicon?

# Design

- Two training conditions
  - 7 positions: ABLE#####, #ABLE#####, ... #####ABLE
  - 1 position (central only): ###ABLE###
- Two training
  - 1179 real four-letter words (McClelland & Rumelhart, 1988)
  - Artificial lexica
- Two testing conditions
  - Transposed letter priming
  - Relative-position priming

# Methods

- Standard feed-forward (backpropagation) neural networks
- Learning: standard gradient descent technique with momentum
  - Learning rate = 0.1
  - Momentum = 0.9
- Number of hidden units = square root of the number of training patterns

# Input coding

- Local coding: 26 letter bits per position (slot)

Presence of letter coding (1 bit per letter)																										
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 1 - Example of encoded input pattern for word ABLE presented in central position (###ABLE###). The first column indicates slot position. In this example, slots 1 to 3 and 6 to 10 contain blanks. This input vector is 260 bits long (10 slots x 26 letters per slot x 1 bit per letter).

# Output coding

- Local coding: one binary output per word

Input vector										Output vector				
A	B	L	E	#	#	#	#	#	#	1	0	0	0	0
#	A	B	L	E	#	#	#	#	#	1	0	0	0	0
#	#	#	#	A	B	L	E	#	#	1	0	0	0	0
W	I	T	H	#	#	#	#	#	#	0	1	0	0	0
#	#	#	#	#	#	W	I	T	H	0	1	0	0	0
#	#	#	T	H	A	T	#	#	#	0	0	0	1	0

Table 2 – Example of input and output for different words presented at different locations (#s represent blanks).

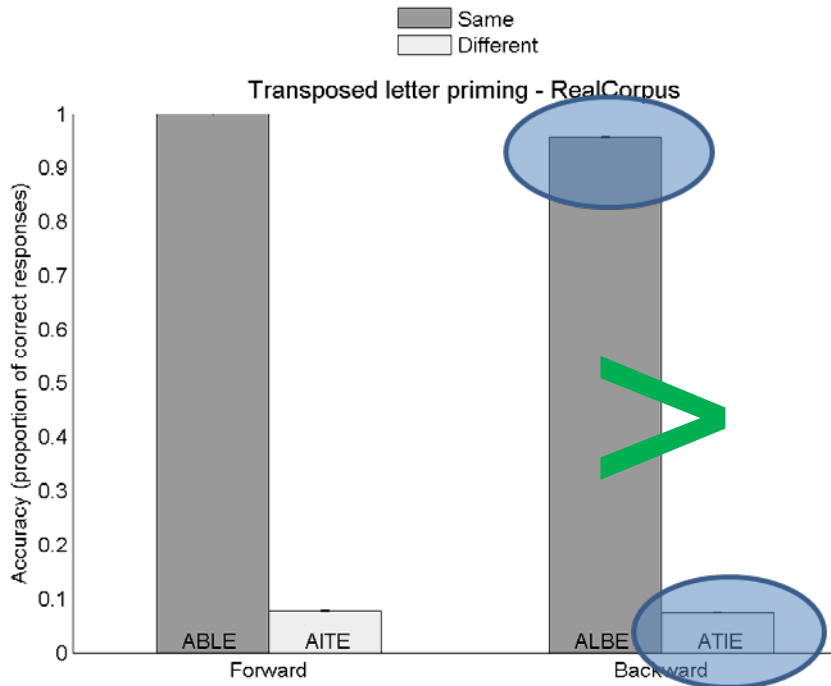
# Transposed-letter priming effect

- Manipulated 2 factors
  - Origin of central letters (same word & different word)
  - Order of central letters (forward & backward)
- Example for target word ABLE

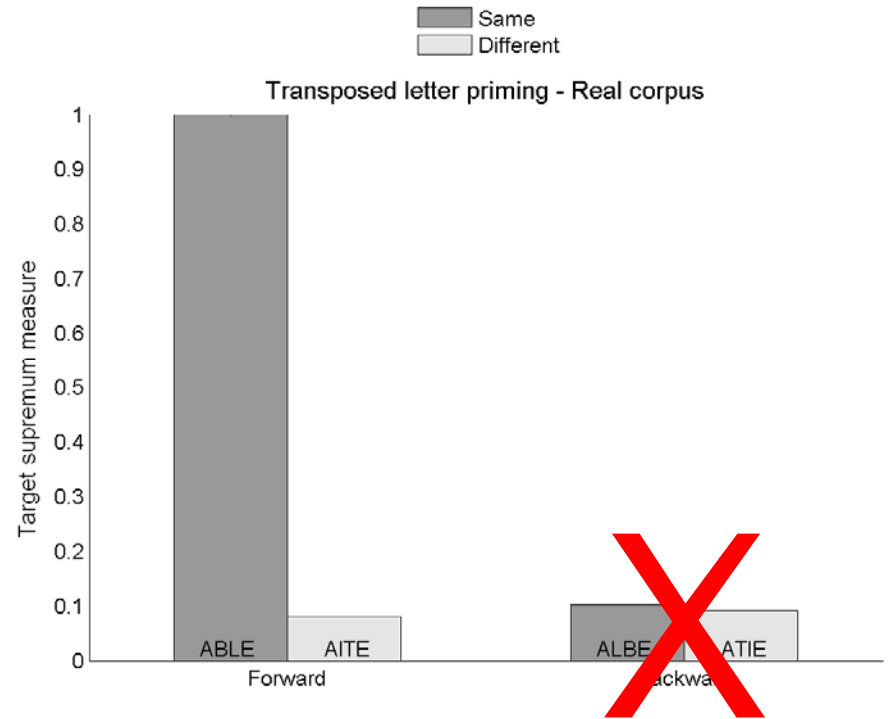
Origin of central letters	Order of central letters	
	Forward	Backward
Same word	ABLE	ALBE
Different word	AITE	ATIE

# Results – Real words

7 positions



1 position (central only)



→ Transposed letter priming effect



7 positions → Forward  $\approx$  Backward



One position → Forward  $>$  Backward

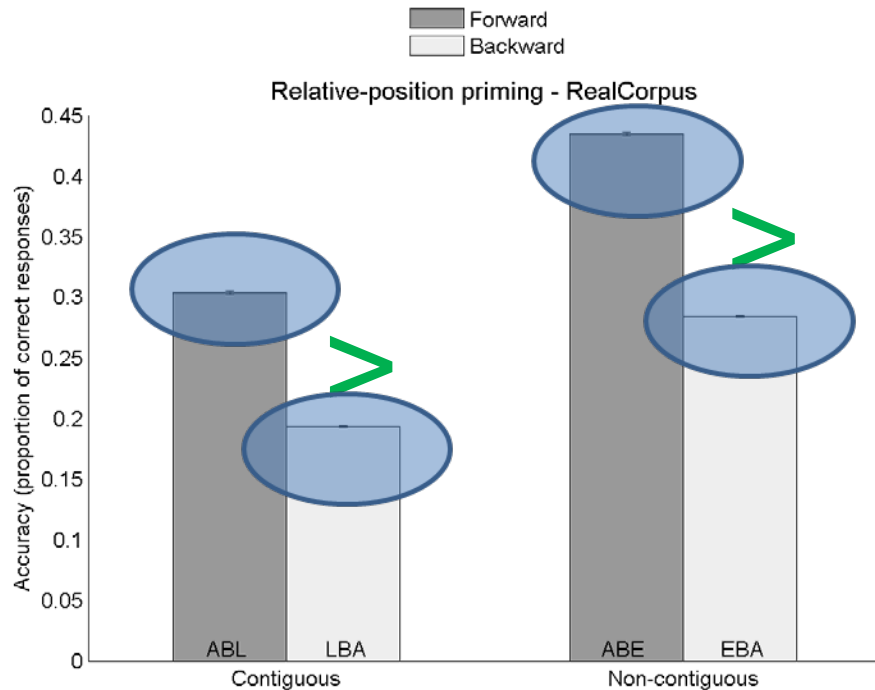
# Relative-position priming effect

- Manipulated 2 factors
  - Letter contiguity (contiguous & non-contiguous)
  - Order of letters in prime (forward & backward)
- Example for target word ABLE

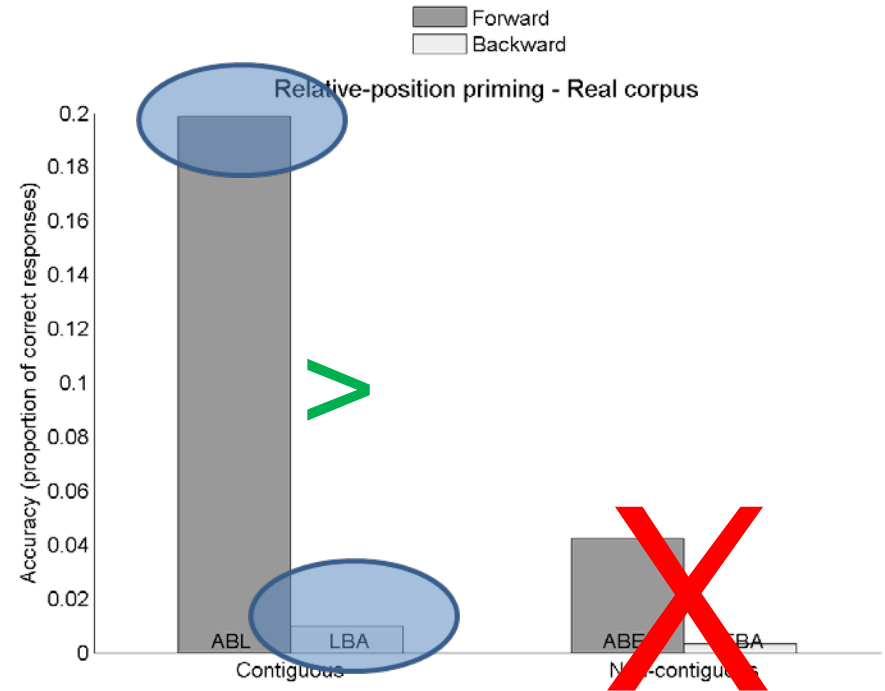
Letter contiguity	Order of letters in prime	
	Forward	Backward
Contiguous	ABL	LBA
	BLE	ELB
Non-contiguous	ABE	EBA
	ALE	ELA

# Results – Real words

7 positions



1 position (central only)



→ Relative-position priming effect

7 positions



Contiguous



Non-Contiguous

One position



Contiguous



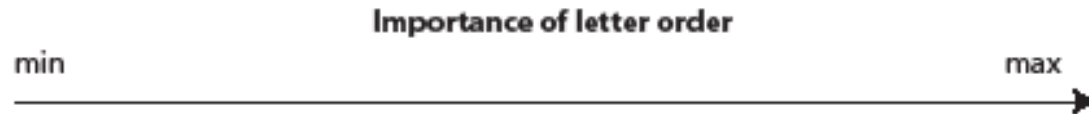
Non-Contiguous

# Artificial lexica

- Further studies with artificial lexica
- Control & manipulate precisely the importance of letter order (e.g., anagrams, orthographic neighbors)

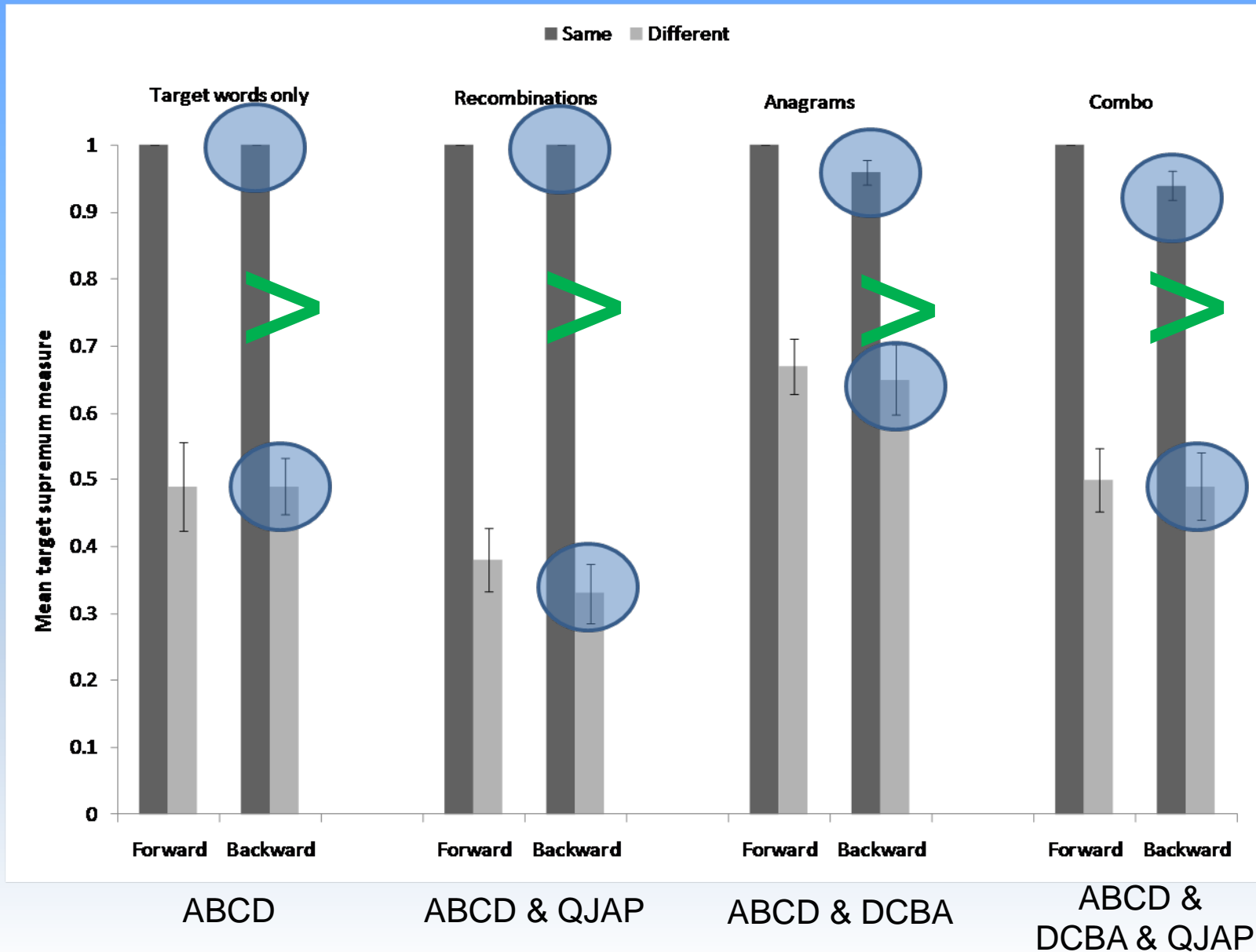
# Artificial training sets

- 5 targets (ABCD, EFGH, IJKL, MNOP, QRST)
- Filler words to manipulate importance of letter order

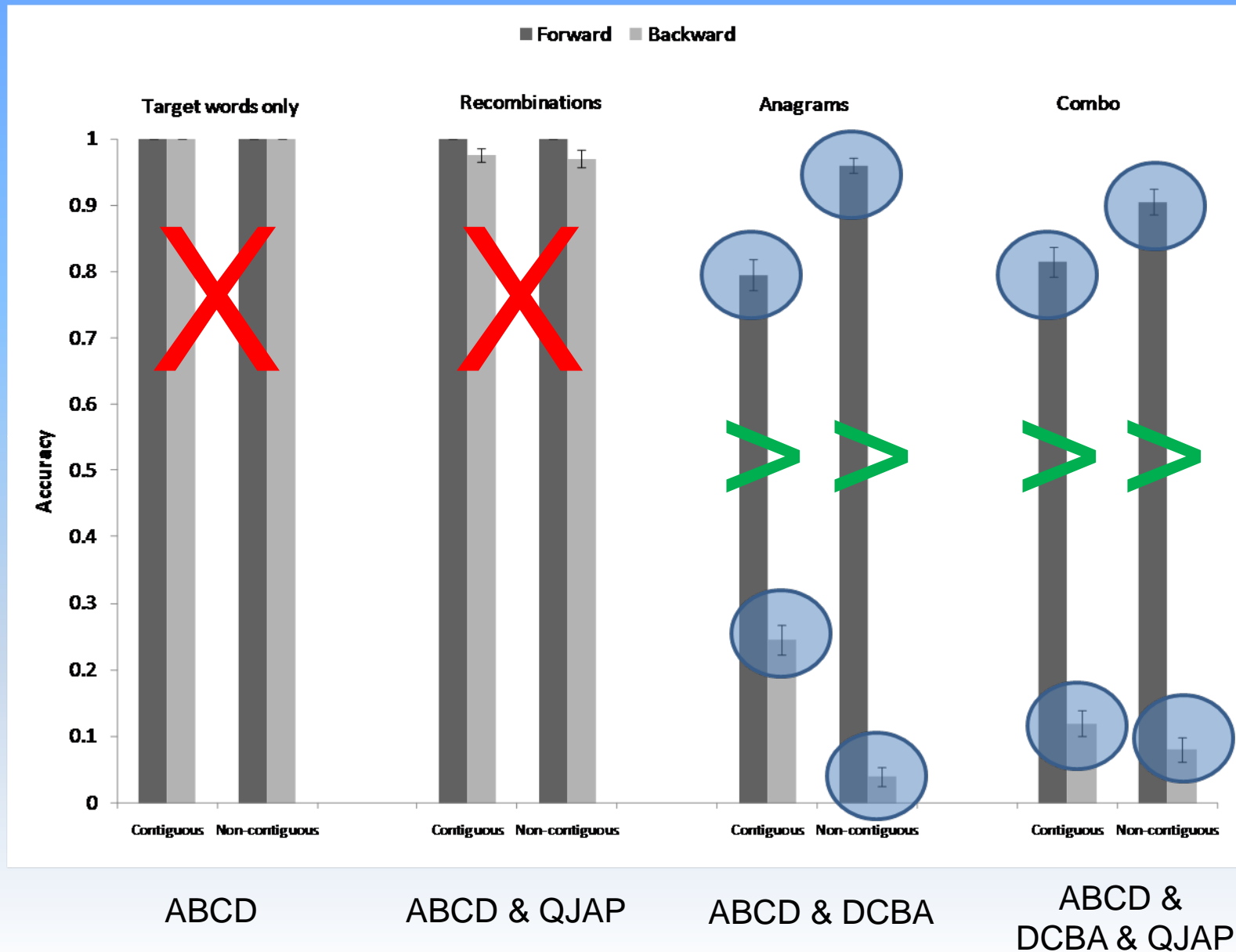


Training sets	Target words	Target words & recombinations	Target words & anagrams	Target words & anagrams & recombinations
Examples containing letter A	ABCD	ABCD & QJAP	ABCD & DCBA	ABCD & DCBA & QJAP

# Results – Transposed letter priming



# Results – Relative-position priming



# Discussion

- Flexible coding naturally emerged in backpropagation networks, under two conditions:
  - Letter order matters in the training set (c.f., target words only)
  - Words are presented at different positions.
- No need to posit uncertainty about letter location (c.f., overlap model)

Thank you for your attention!

## Collaborators

Jonathan Grainger

Stéphane Dufau

## Funding



# References

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