Rastle, K. (2017). Writing systems, reading, and language. EPS Mid-Career Prize Lecture, presented at the Experimental Psychology Society meeting, July 13, 2017, Reading, England.

Writing systems, reading and language

Kathy Rastle

Reading EPS, 2017

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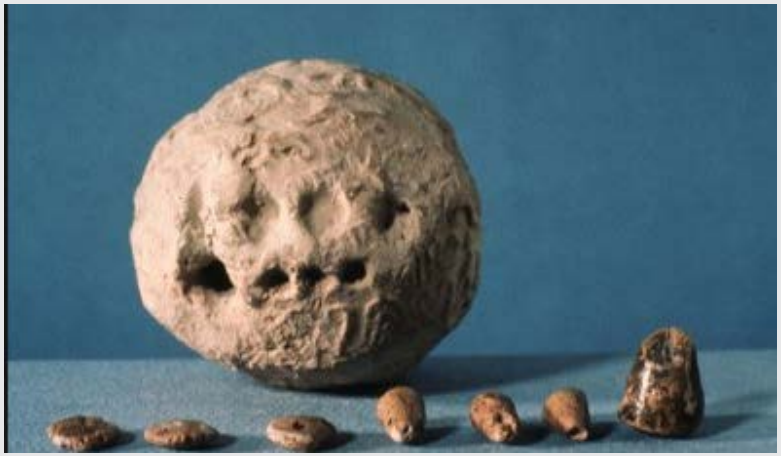
@kathy_rastle
www.rastlelab.com

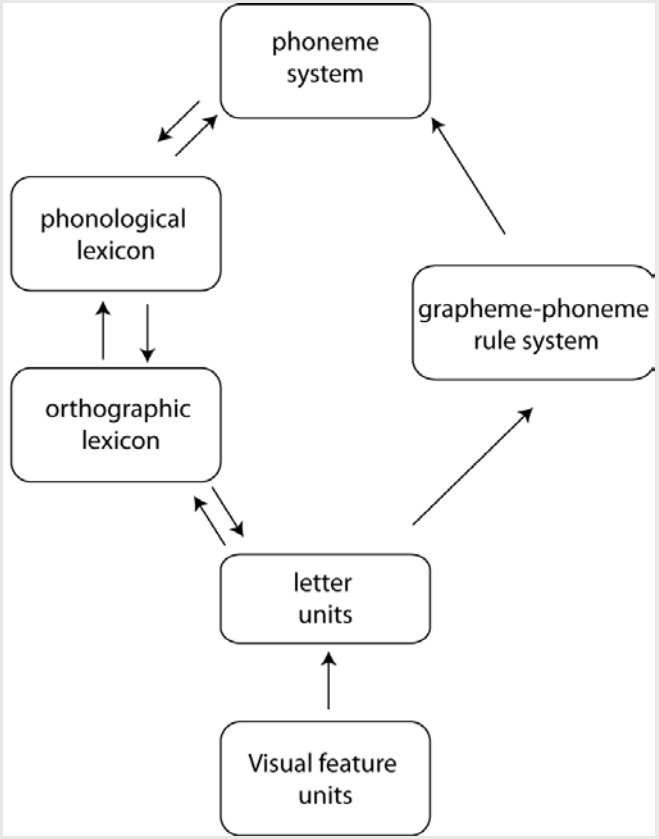
Writing and human capability



Sproat (2010)
Schmandt-Besserat (1996)

Studying reading in Australia

The DRC model of reading

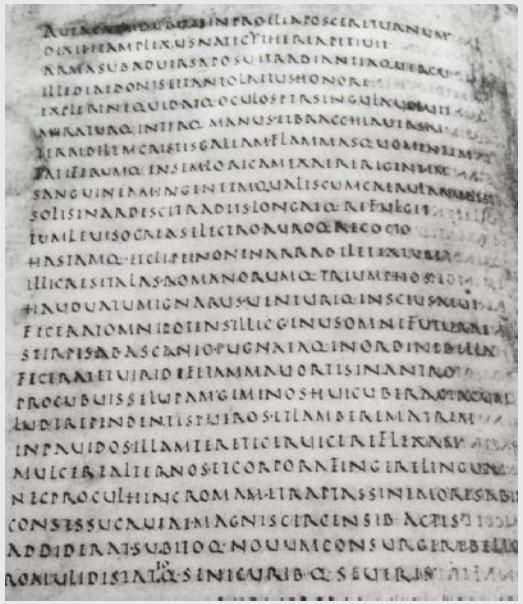


Max Coltheart

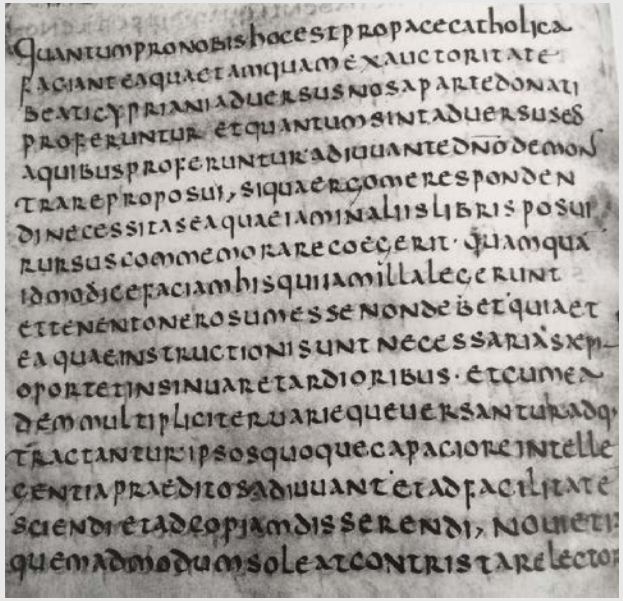
- Model of skilled reading behaviour
- Translation of spelling to sound (reading aloud)
- The brain is irrelevant

Coltheart & Rastle (1994)
Rastle & Coltheart (1998, 1999, 2000)
Coltheart, Rastle, Perry, Langdon & Ziegler (2001)

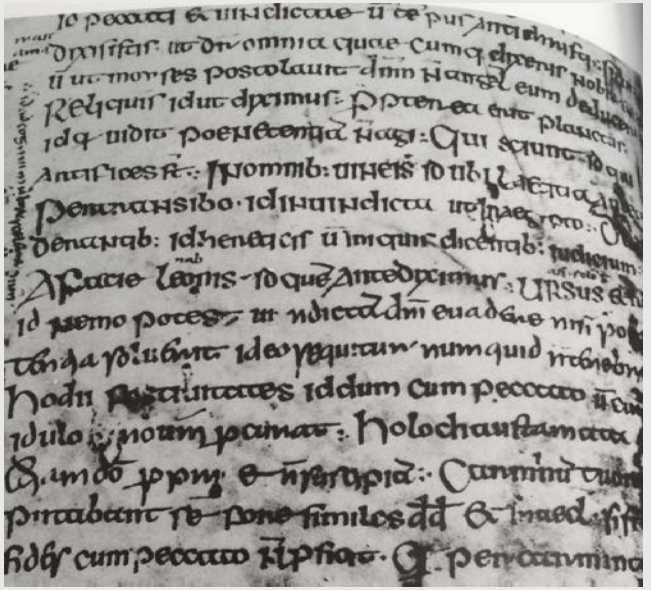
What is writing?



Italy, 5th century



Spain, 7th century



Ireland, 7th century

- Developed in parallel with silent reading
- Developed largely in Ireland

Parkes (1992)
Saenger (1997)

Writing systems

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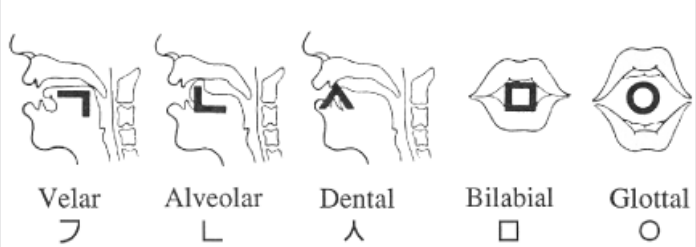
	g	n	d	r	m	b	s	o	j	ch	k	t	p	h
a	가 ga	나 na	다 da	라 ra	마 ma	바 ba	사 sa	아 a	자 ja	차 cha	카 ka	타 ta	파 pa	하 ha
ya	갸 gya	냐 nya	댜 dya	랴 rya	먀 mya	뱌 bya	샤 sya	야 ya	쟈 jya	챠 chya	캬 kya	탸 tya	퍄 pya	햐 hya
eo	거 geo	너 neo	더 deo	러 reo	머 meo	버 beo	서 seo	어 eo	저 jeo	처 cheo	커 keo	터 teo	퍼 peo	허 hya
yeo	겨 gyeo	녀 nyeo	뎌 dyeo	려 ryeo	며 myeo	벼 byeo	셔 syeo	여 yeo	져 jyeo	쳐 chyeo	켜 kyeo	텨 tyeo	펴 pyeo	혀 hyeo
o	고 go	노 no	도 do	로 ro	모 mo	보 bo	소 so	오 o	조 jo	초 cho	코 ko	토 to	포 po	호 ho
yo	교 gyo	뇨 nyo	됴 dyo	료 ryo	묘 myo	뵤 byo	쇼 sya	요 yo	죠 jyo	쵸 chyo	쿄 kyo	툐 tyo	표 pyo	효 hyo
u	구 gu	누 nu	두 du	루 ru	무 mu	부 bu	수 su	우 u	주 ju	추 chu	쿠 ku	투 tu	푸 pu	후 hu
yu	규 gyu	뉴 nyu	듀 dyu	류 ryu	뮤 myu	뷰 byu	슈 syu	유 yu	쥬 jyu	츄 chyu	큐 kyu	튜 tyu	퓨 pyu	휴 hyu
eu	그 geu	느 neu	드 deu	르 reu	므 meu	브 beu	스 seu	으 eu	즈 jeu	츠 cheu	크 keu	트 teu	프 peu	흐 heu
i	기 gi	니 ni	디 di	리 ri	미 mi	비 bi	시 si	이 i	지 ji	치 chi	키 ki	티 ta	피 pi	히 hi
ae	개 gae	내 nae	대 dae	래 rae	매 mae	배 bae	새 sae	애 ae	재 jae	채 chae	캐 kae	태 tae	패 pae	해 hae



Upper case

ABCDEFGHIJKLMNOPQRSTUVWXYZ

Lower case

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

English writing system

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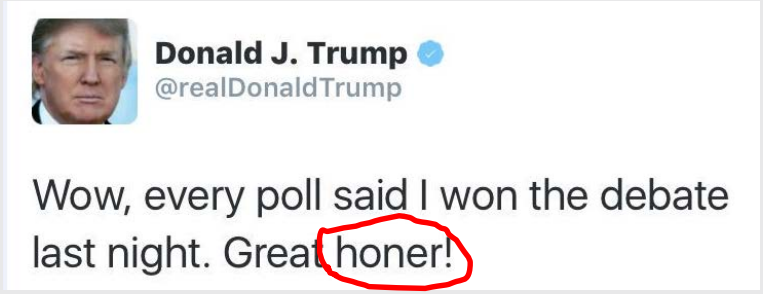
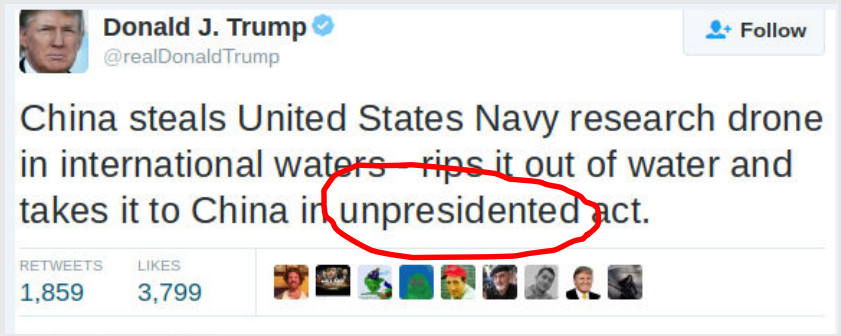
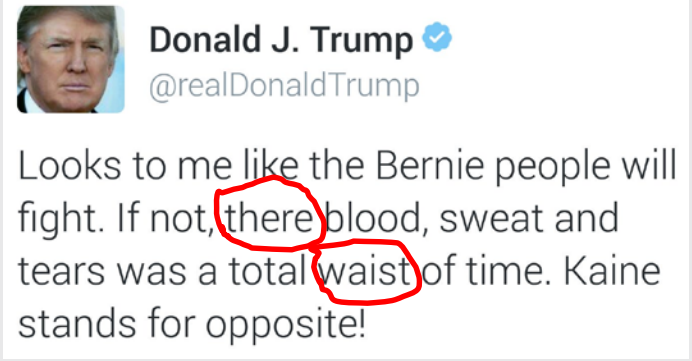
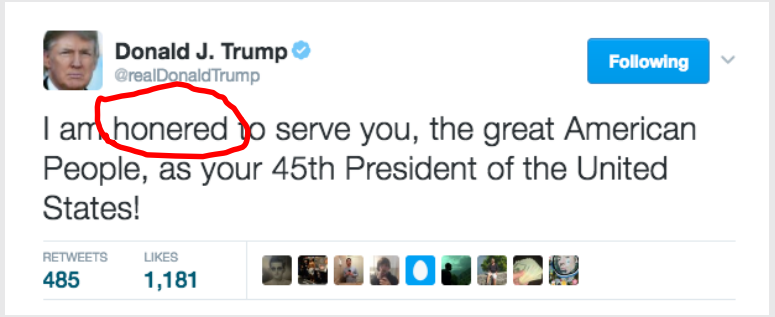
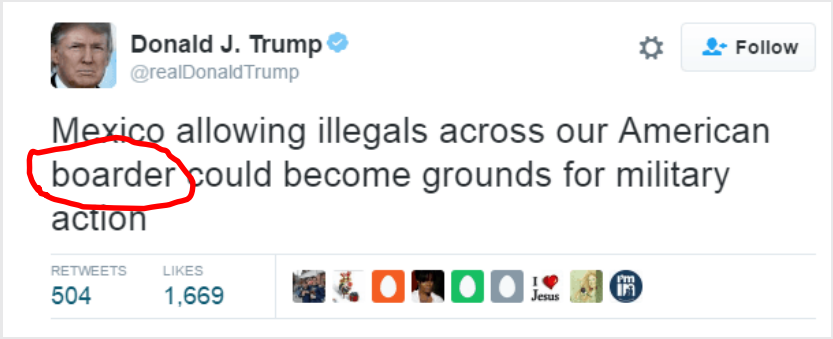




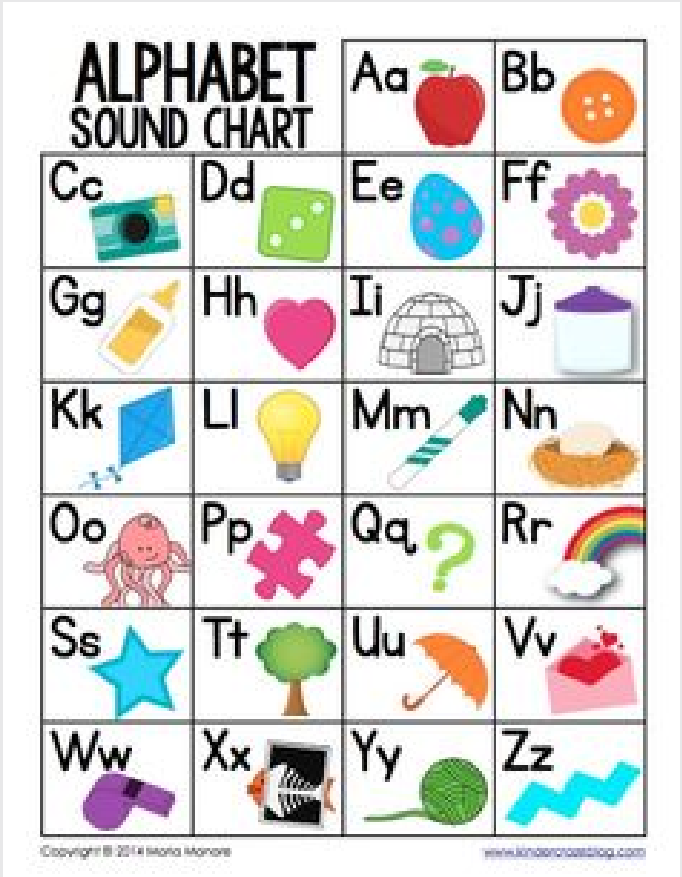






The information in English writing

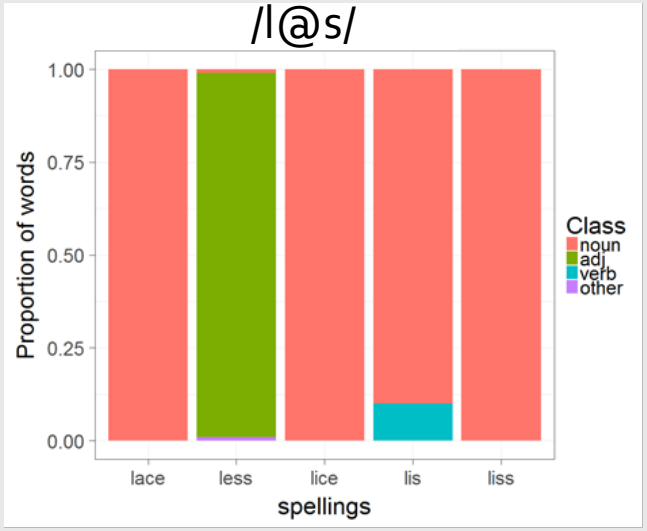
High inconsistency between spellings and sounds

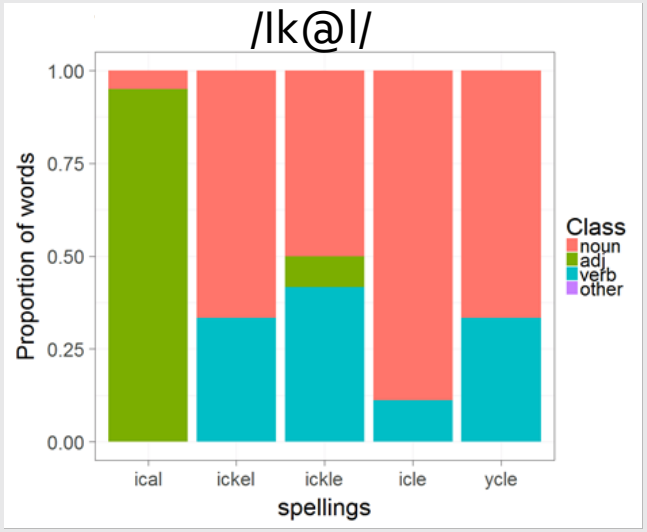


Ana Ulicheva & Mark Aronoff

- Trade spelling-sound consistency for meaningful information (magician, health)
- Trade sound-spelling consistency for meaningful information (affixes; e.g. -less, -ical)

The information in English writing

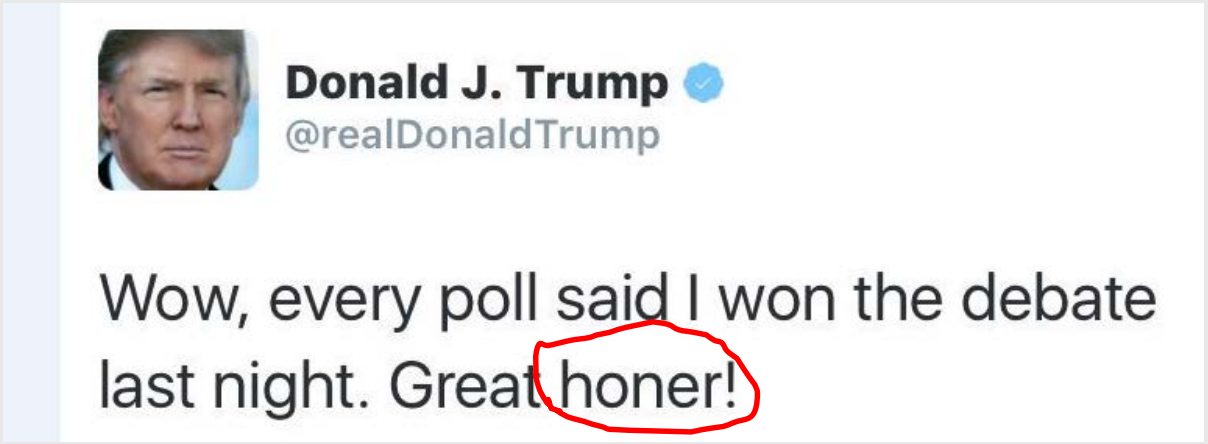




Ana Ulicheva & Mark Aronoff

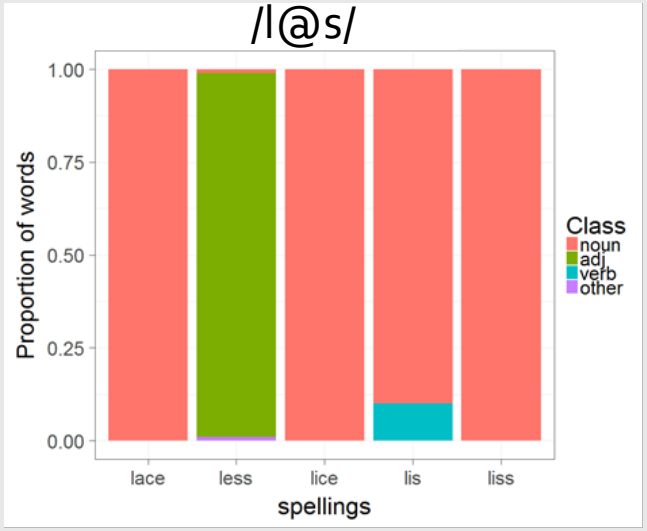
- Trade spelling-sound consistency for meaningful information (magician, health)
- Trade sound-spelling consistency for meaningful information (affixes; e.g. -less, -ical)
- Information not available in spoken language
- English system is anarchic and self-organising

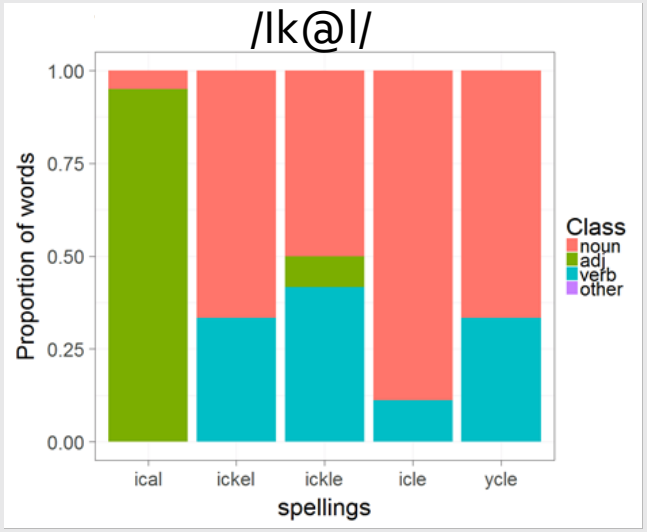
What's wrong with 'honer'?



- 'honer' can be parsed into [hone] + [-er] (i.e. someone who hones)
- 'honer' was an acceptable spelling for 'honour' between c. XV and XVII but disappears when 'hone' first used as a verb
- Same sound sequence; optimal spelling reduces ambiguity, facilitates access to meaning

The information in English writing

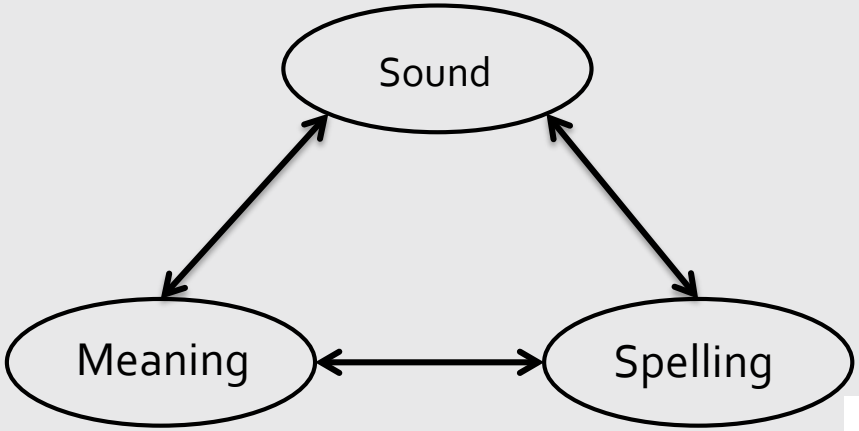




Ana Ulicheva & Mark Aronoff

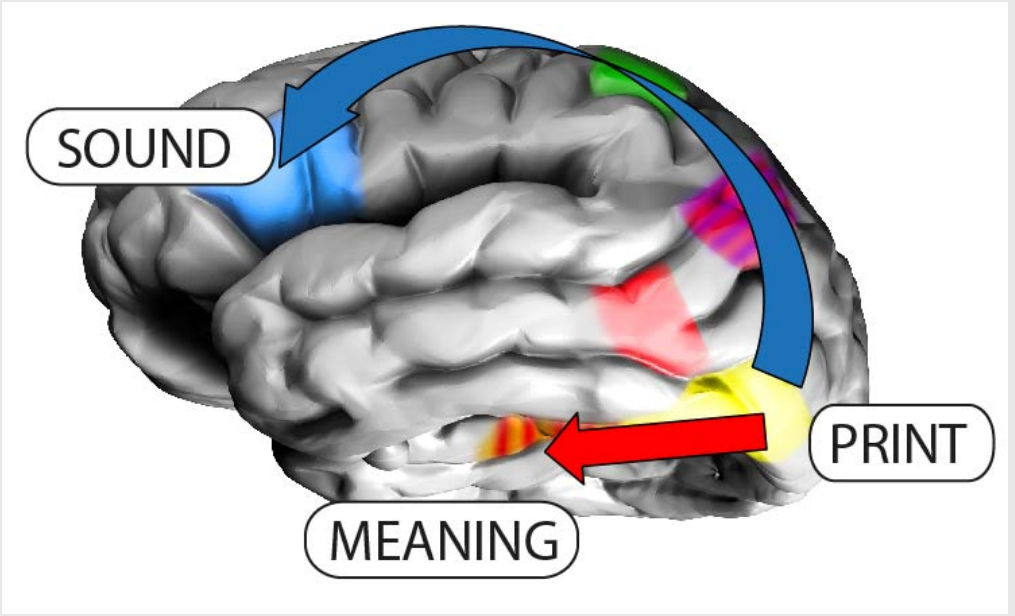
- Trade spelling-sound consistency for meaningful information (magician, health)
- Trade sound-spelling consistency for meaningful information (affixes; e.g. -less, -ical)
- Information not available in spoken language
- English system is anarchic and self-organising
- Just scratching the surface!

Our working framework



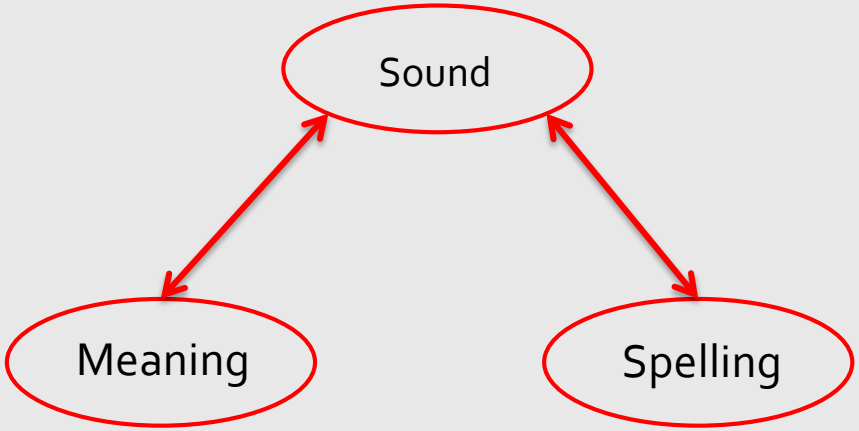
Jo Taylor & Matt Davis

How are spelling-sound and spelling-meaning regularities present in the writing system expressed in the reading system?

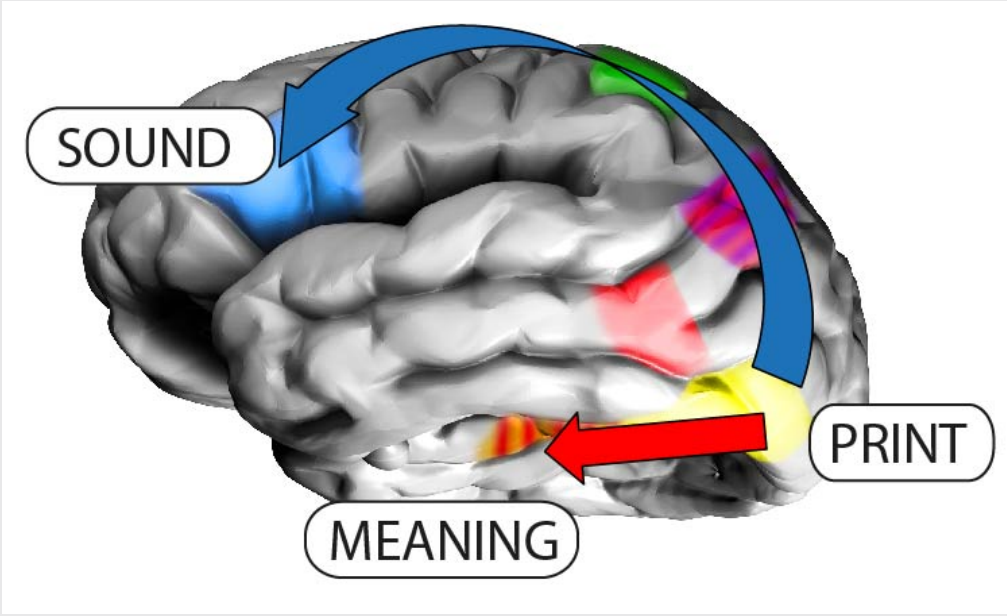


Taylor, Rastle & Davis (2013) Psychological Bulletin

Spelling-sound mapping, reading acquisition



- Substantial evidence that acquisition is vital in early reading
- Phonics
- Hook into spoken language knowledge



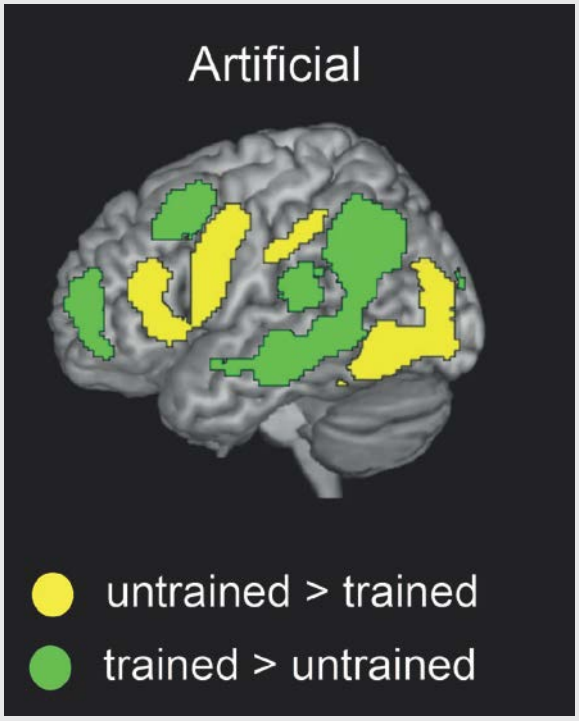
Spelling-sound mapping, reading acquisition

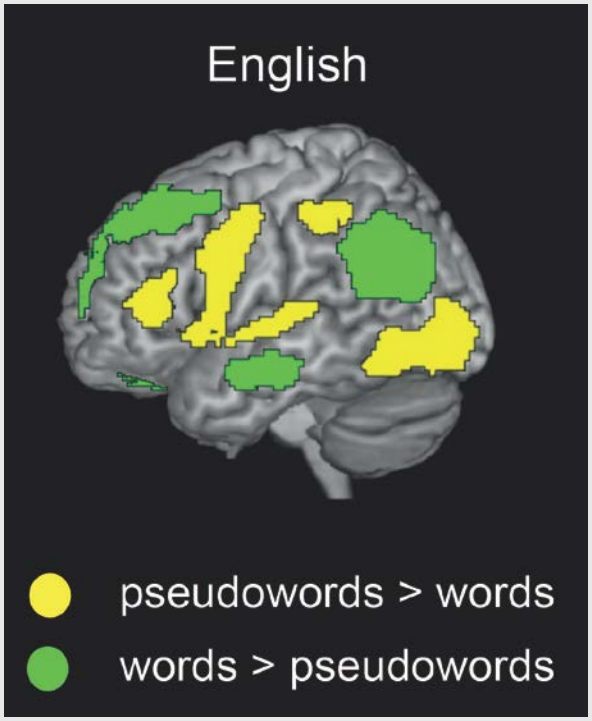
gVk

faIm

kEs

Jo Taylor & Matt Davis





Taylor, Davis & Rastle (2017) JEP:GEN

Spelling-sound mapping, reading acquisition

kEs

faIm

gVk

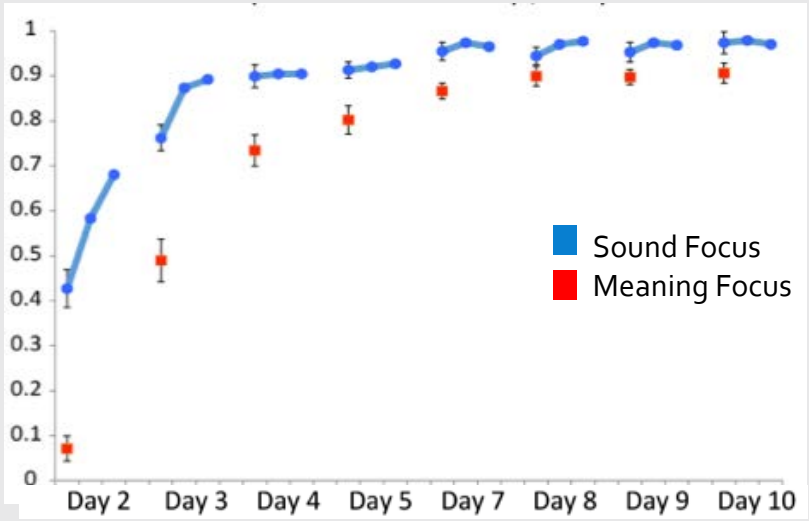
bAv

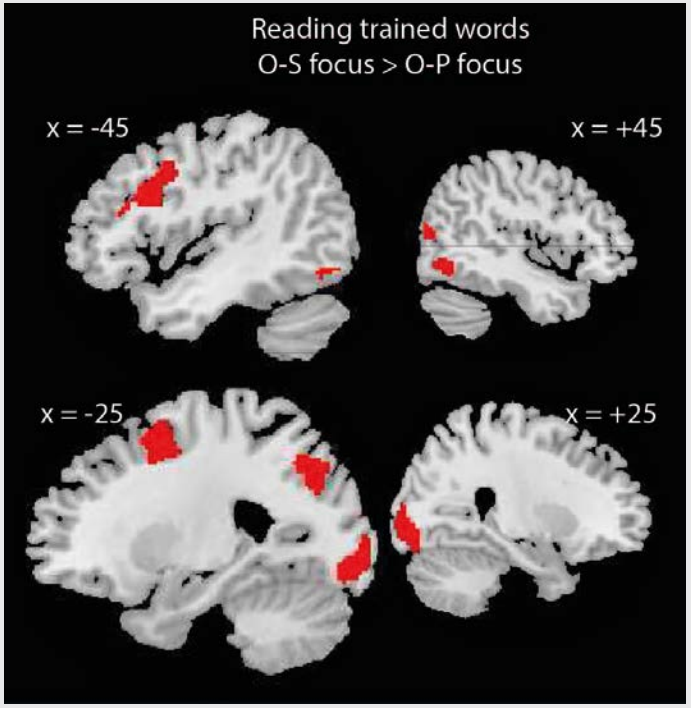
sif

vuz

Jo Taylor & Matt Davis

Reading Aloud Accuracy





Taylor, Davis & Rastle (2017) JEP:GEN

Spelling-sound mapping, reading acquisition

kEs

faIm

gVk

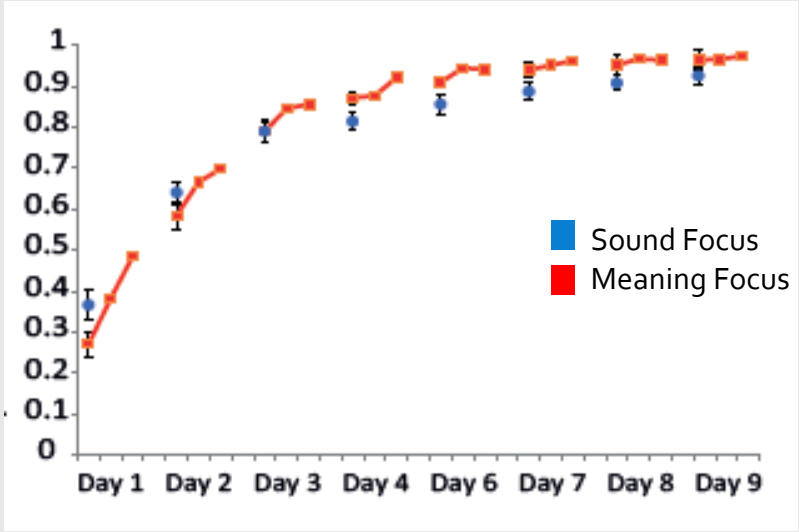
bAv

sif

vuz

Jo Taylor & Matt Davis

Saying the Meaning Accuracy



No neural effort effects; saying the meaning equally difficult in spelling-sound and spelling-meaning training conditions

Learning to read an alphabetic system requires appreciation of spelling-sound relationship; information represented in dorsal pathway.

Taylor, Davis & Rastle (2017) JEP:GEN

Spelling-sound mapping, skilled reading

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What is the nature of spelling-sound knowledge used in skilled reading?

Betty Mousikou

bamper
prulli
vundle
diswaps
congeave
enplouch
explave
unbove
tuleg
bancing
meapless
laniff
eluch
survact
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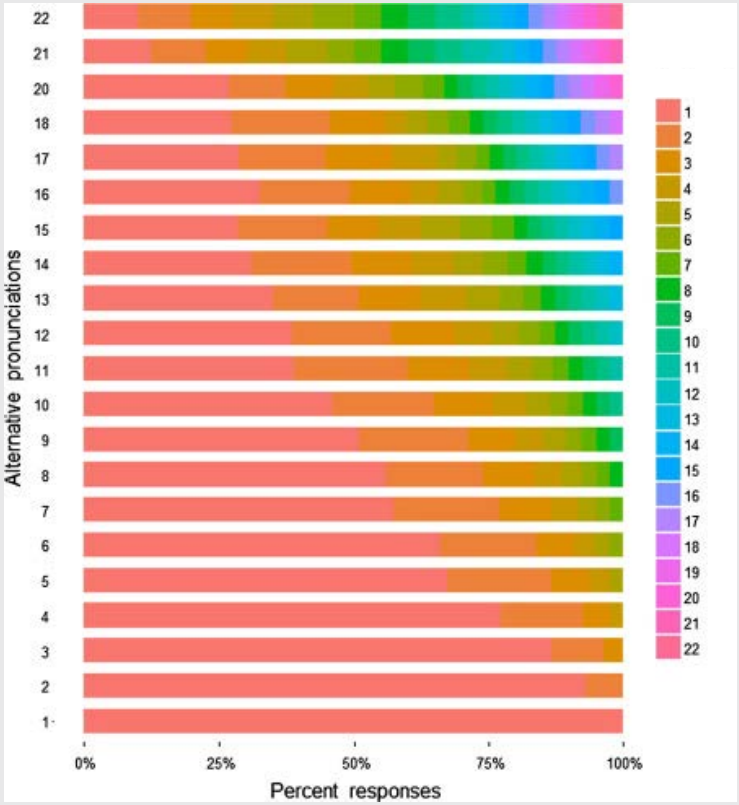
ucide



- Variation strongly attributable to regularities in the writing system
- Pronunciation variability predicted by strength of spelling-sound mapping for units in English

915 disyllabic nonwords * 41 subjects

Mousikou, Sadat, Lucas & Rastle (2017) JML

Spelling-sound mapping, skilled reading

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What is the nature of spelling-sound knowledge used in skilled reading?

Betty Mousikou

BAMPER

b	**am**	**p**	**er**	
100%	92%	100%	98%	pronunciation
96%	87%	56%	98%	1st syll stress

ELUCH

e	**l**	**uch**	
65%	100%	50%	pronunciation
13%	74%	100%	1st syll stress

- Variation strongly attributable to regularities in the writing system
- Pronunciation variability predicted by strength of spelling-sound mapping for units in English
- Stress variability predicted by strength of spelling-stress mapping for units in English
- Effects also arise *within* individuals

Mousikou, Sadat, Lucas & Rastle (2017) JML

Spelling-sound mapping, skilled reading

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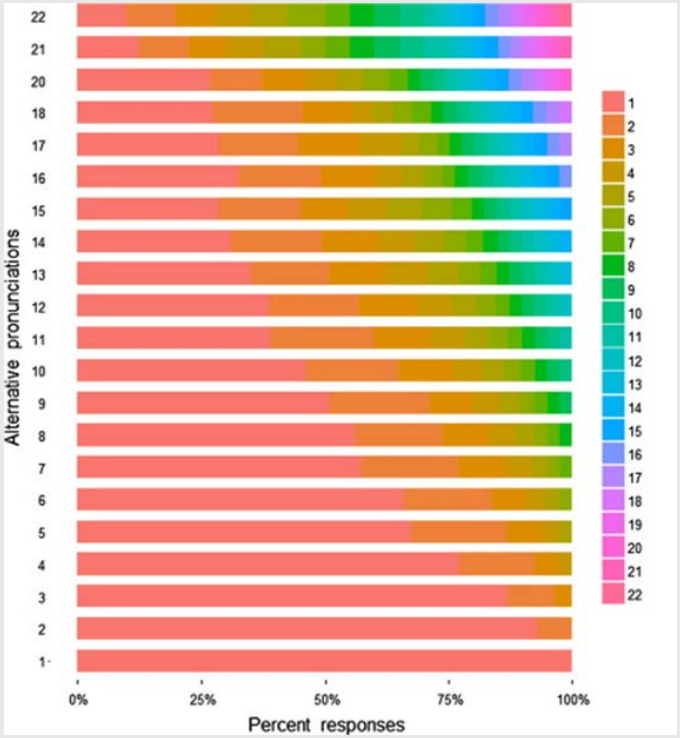
What is the nature of spelling-sound knowledge used in skilled reading?

Betty Mousikou

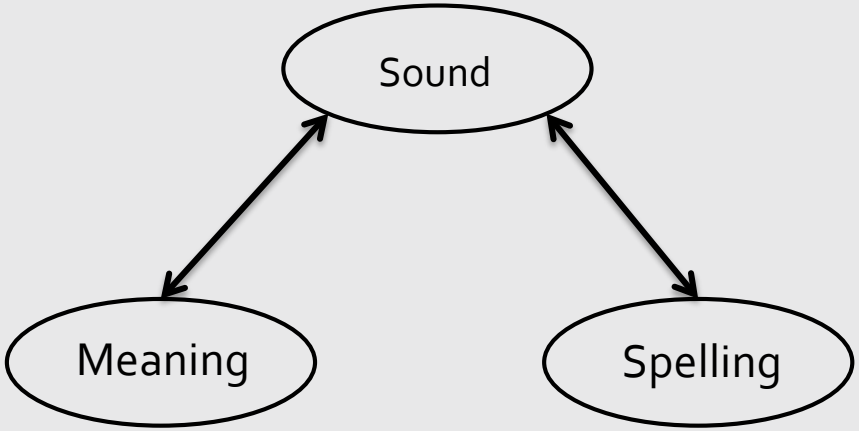


Spelling-sound knowledge mirrors statistical regularities in the writing system; considerable uncertainty in areas of mapping for skilled readers

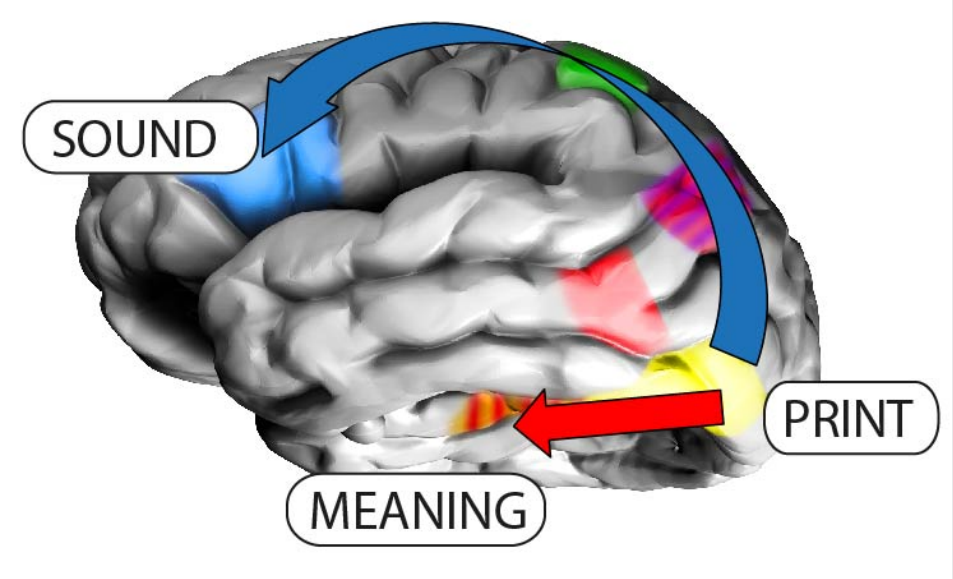
- Variation strongly attributable to regularities in the writing system
- Pronunciation variability predicted by strength of spelling-sound mapping for units in English
- Stress variability predicted by strength of spelling-stress mapping for units in English
- Effects also arise *within* individuals

Mousikou, Sadat, Lucas & Rastle (2017) JML

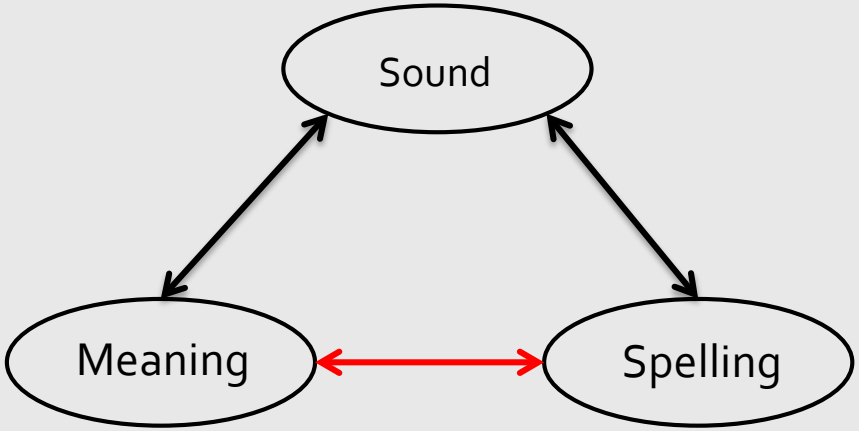
Spelling-sound mapping, summary

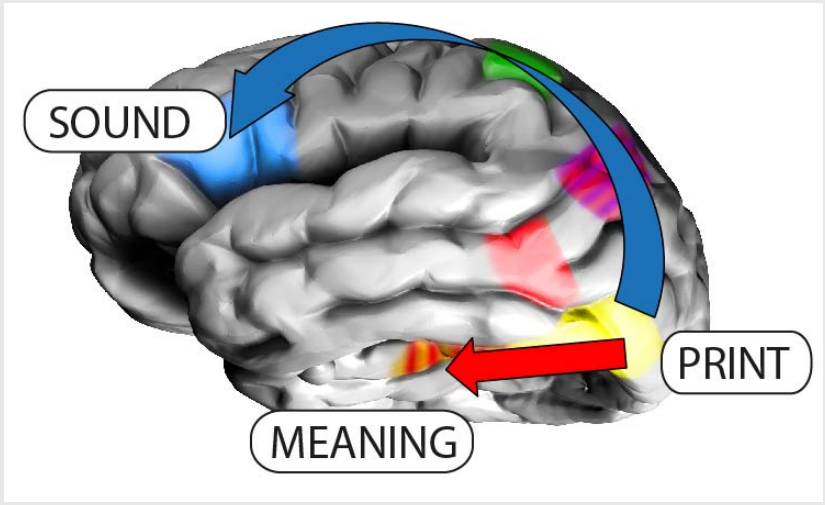


- Primary regularity in alphabetic writing systems; critical in reading acquisition
- Underpinned by dorsal brain pathway
- Spelling-sound knowledge mirrors regularities in writing system
- Can spelling-sound knowledge support skilled, English reading?

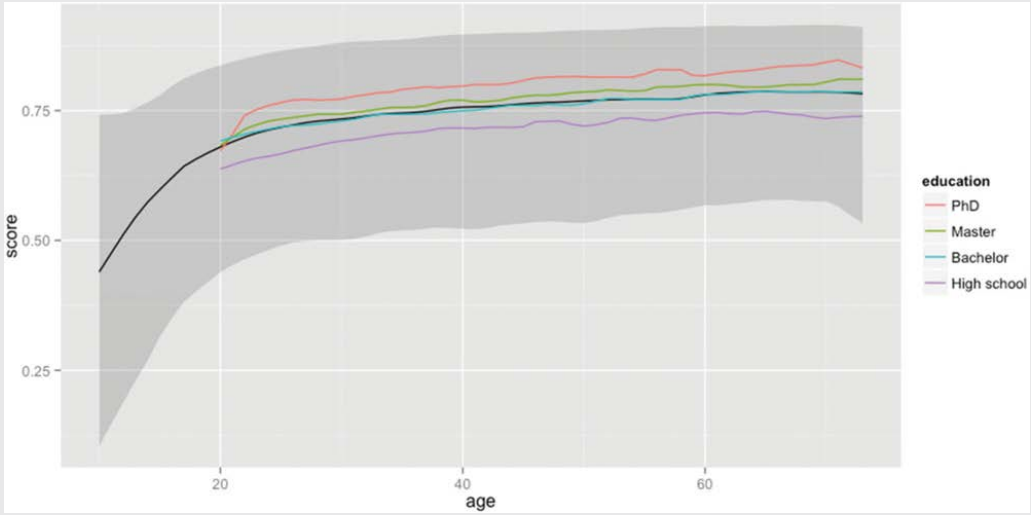


Spelling-sound necessary, not sufficient

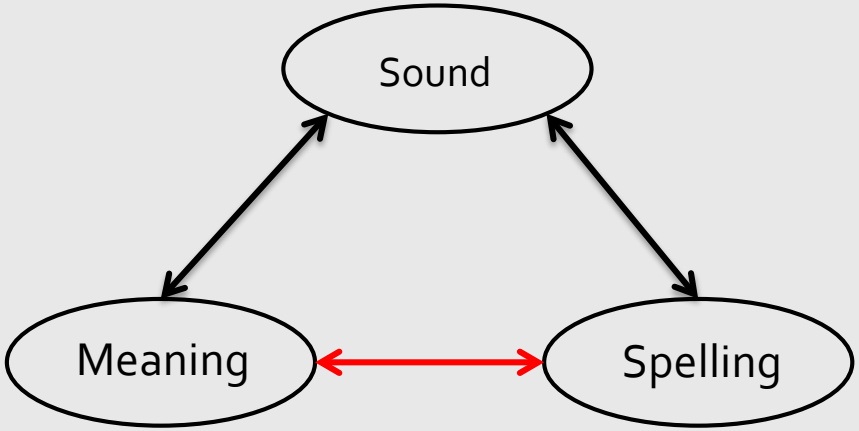




- Development of expertise, laying down of long-term experience
- Regions of ventral pathway changing in sensitivity into adolescence *(Ben Shachar et al., 2011)*
- Substantial growth in number of words recognised between age 20 and 60; especially in periods of education *(Brysbaert et al., 2016)*



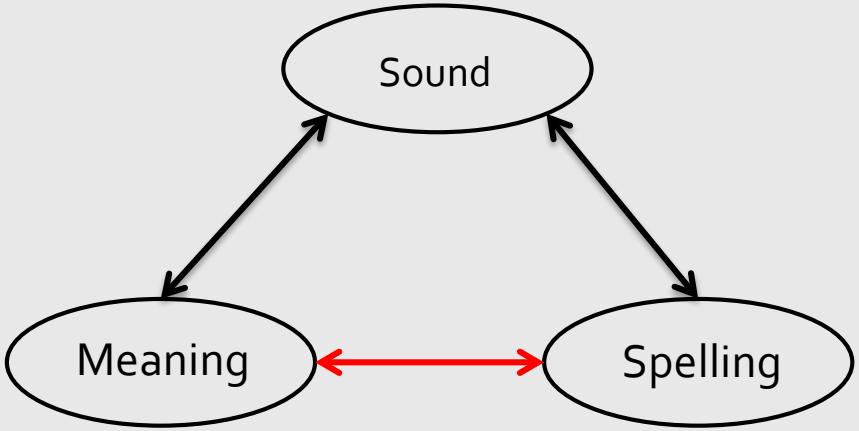
Morphology and spelling-meaning mapping



- Item-level "orthographic learning" *(e.g. Nation, 2017)*; interested in global impact of capturing spelling-meaning regularities
- Morphology dramatically reduces scale of the learning challenge
- Average 20 year old – 71,000 word forms -> 42,000 lemmas -> 11,100 base words *(Brysbaert et al., 2016)*

develop, develops, developing, developed, developer(s), undeveloped, undevelopable, developable, development(s), developmental, developmentally, antidevelopment, redevelop, predevelop, predevelopment

Morphology and spelling-meaning mapping



- To appreciate meaningful connection input must be structured; need to discover spelling-meaning regularities
- Proliferation of spellings makes it possible for some spellings to be reserved as affixes
- How do we represent and use spelling-meaning knowledge, and how is it learned?

	develop			
	develop	s		
	develop	ing		
	develop	ed		
	develop	er	s	
un	develop	ed		
un	develop	able		
	develop	able		
	develop	ment		
	develop	ment	al	
	develop	ment	al	ly
anti	develop	ment		
re	develop			
pre	develop			
pre	develop	ment		

Morphology and word recognition

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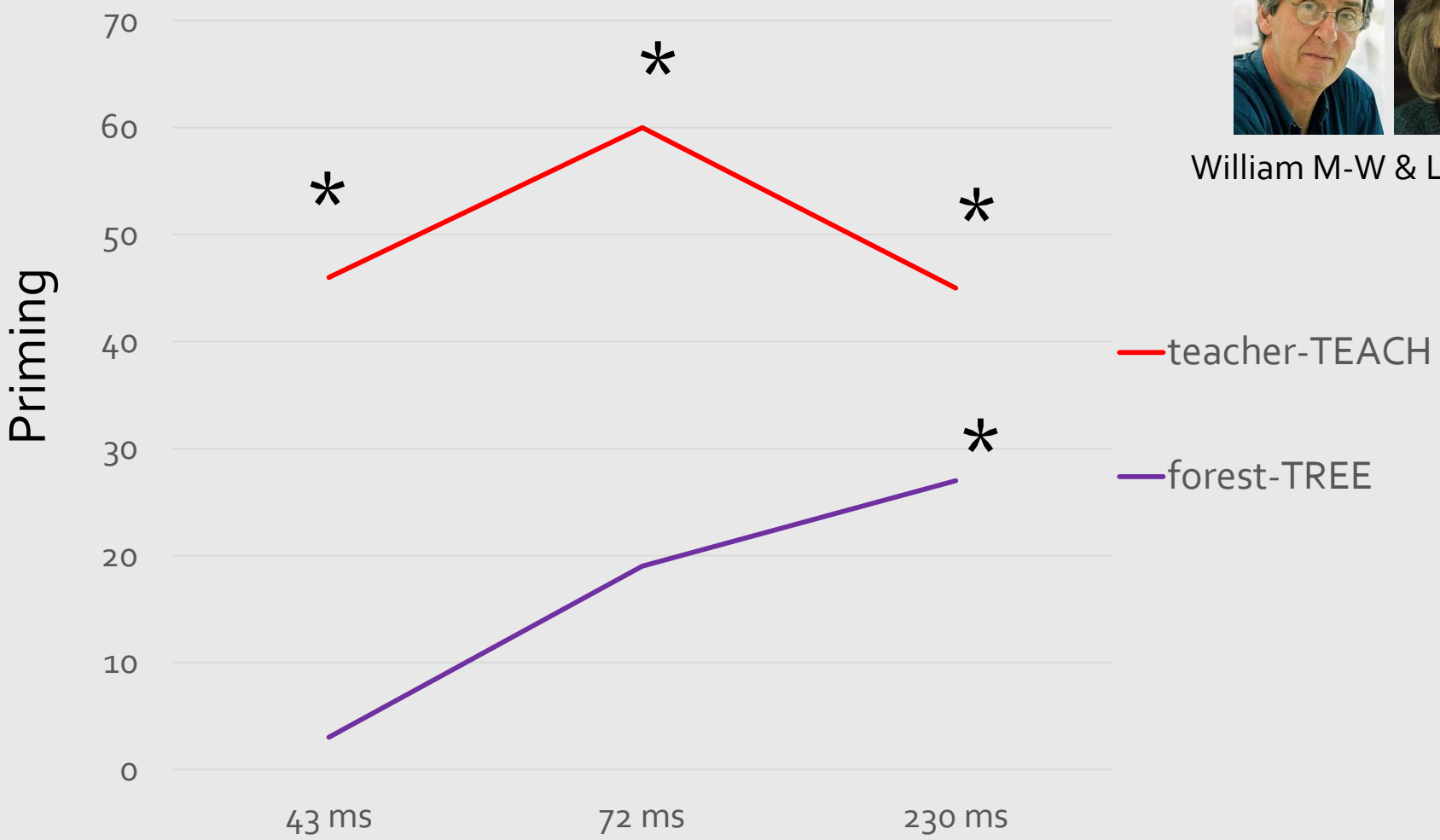
William M-W & Lolly Tyler



Rastle, Davis, Marslen-Wilson & Tyler (2000) LCP

Morphology and word recognition

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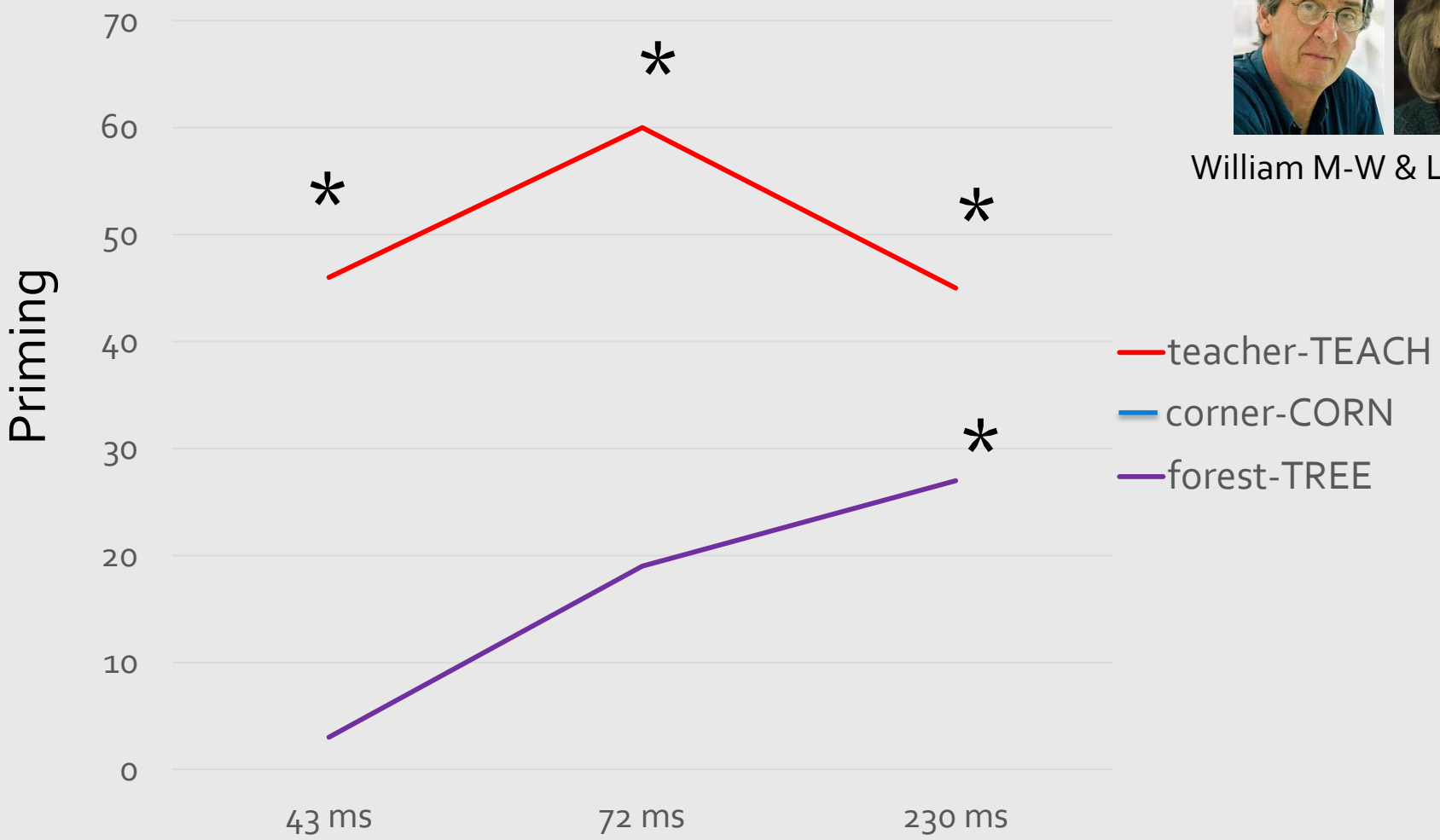
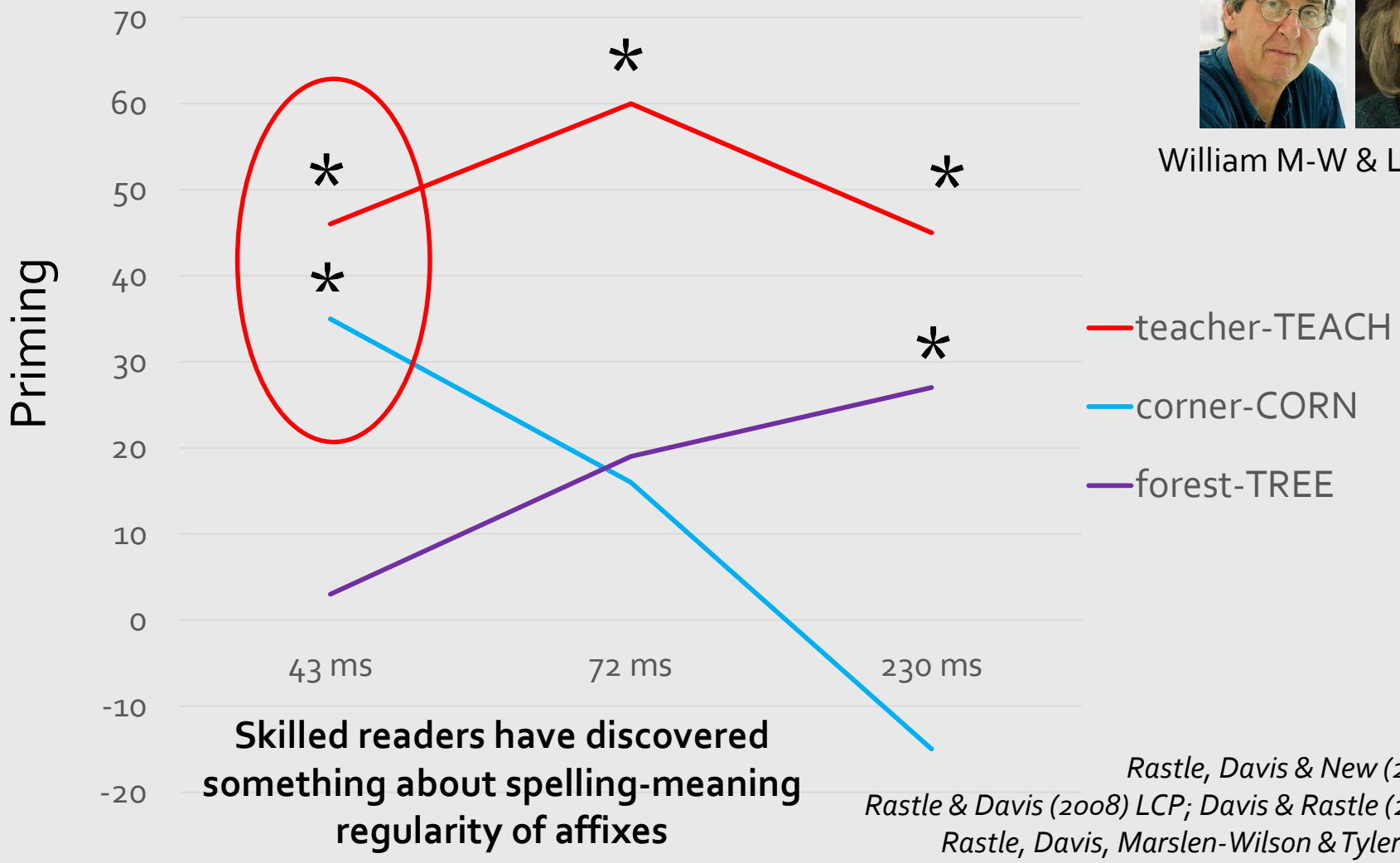
William M-W & Lolly Tyler



Rastle, Davis, Marslen-Wilson & Tyler (2000) LCP

Morphology and word recognition

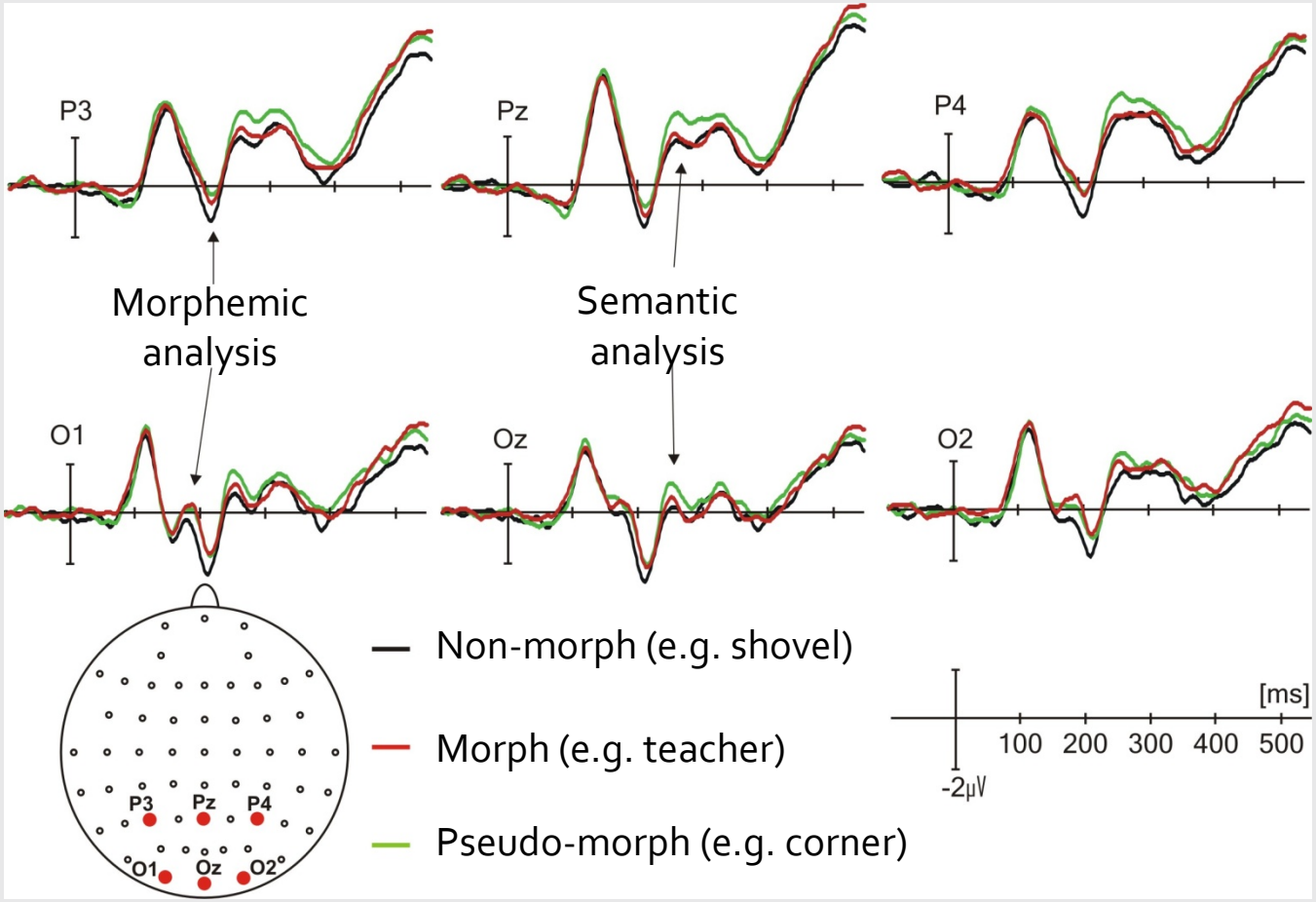
William M-W & Lolly Tyler



Skilled readers have discovered something about spelling-meaning regularity of affixes

Rastle, Davis & New (2004) PB&R
Rastle & Davis (2008) LCP; Davis & Rastle (2010) PB&R
Rastle, Davis, Marslen-Wilson & Tyler (2000) LCP

Morphology and word recognition



A. Lavric & D. Crepaldi

- Rapid morphological analysis ~190 ms
- Semantic analysis / integration ~250 ms

Rapid, superficial analysis; only possible because of nature of the writing system

Lavric, Elchlepp & Rastle (2012), JEP:HPP
Rastle, Lavric, Elchlepp & Crepaldi (2015) JEP:HPP

Acquisition of spelling-meaning knowledge

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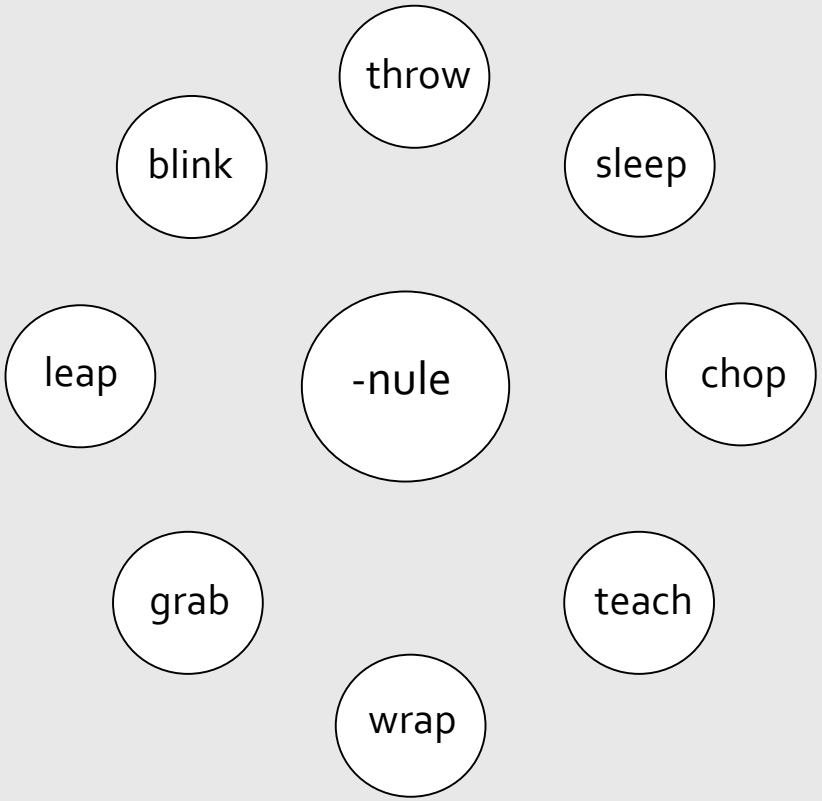
- How do we acquire representations that permit us to conduct this superficial analysis?
  - Skilled readers' knowledge mirrors consistency of the mapping from spelling to function *(Ulicheva, Aronoff & Rastle, Friday 9.30am)*
  - Laboratory acquisition driven by contextual diversity and spelling-meaning consistency *(Tamminen, Davis, & Rastle, 2015, Cognitive Psychology)*

kindness
greatness
sweetness
blindness
weakness
thickness
illness
dizziness
happiness
awareness
goodness
sickness
darkness
wickedness

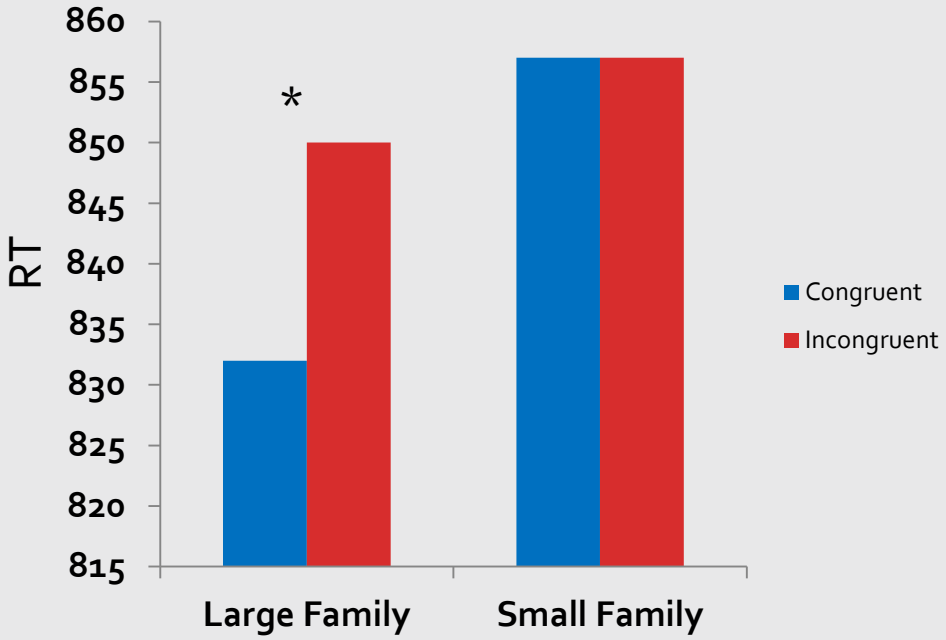
Acquisition of spelling-meaning knowledge

J. Tamminen



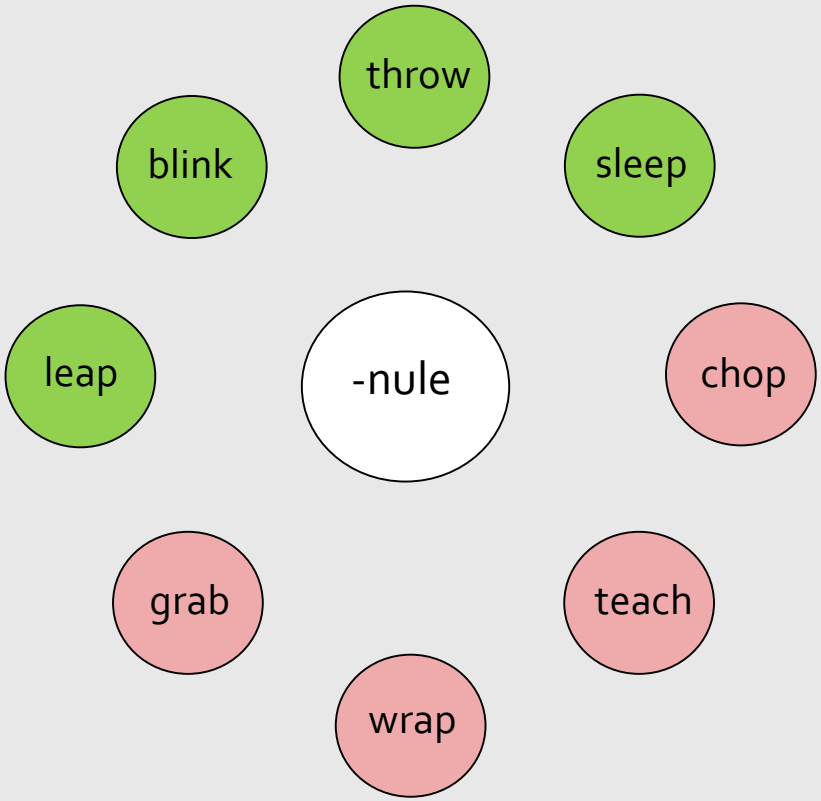
Contextual diversity critical for learning

The manager often argued with the … *drinknule*
Yesterday, she snuck into the … *printnule*



Tamminen, Davis & Rastle (2015) Cognitive Psychology

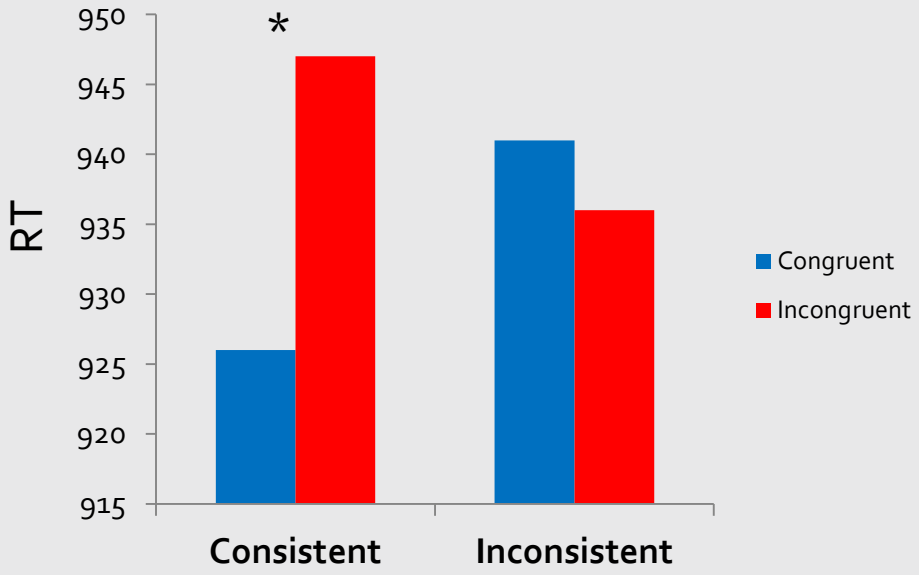
Acquisition of spelling-meaning knowledge



Spelling-meaning consistency critical for learning

J. Tamminen

The manager often argued with the … *drinknule*
Yesterday, she snuck into the … *printnule*



Tamminen, Davis & Rastle (2015) Cognitive Psychology

Acquisition of spelling-meaning knowledge

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- How do we acquire representations that permit us to conduct this superficial analysis?
  - Skilled readers' knowledge mirrors consistency of the mapping from spelling to function *(Ulicheva, Aronoff & Rastle, Friday 9.30am)*
  - Laboratory acquisition driven by contextual diversity and spelling-meaning consistency *(Tamminen, Davis, & Rastle, 2015, Cognitive Psychology)*
- We acquire knowledge of spellings that consistently signify particular meanings or functions, and which arise repeatedly in combination with known stems; portrayed in skilled readers

kindness
greatness
sweetness
blindness
weakness
thickness
illness
dizziness
happiness
awareness
goodness
sickness
darkness
wickedness

Morphology and the ventral pathway

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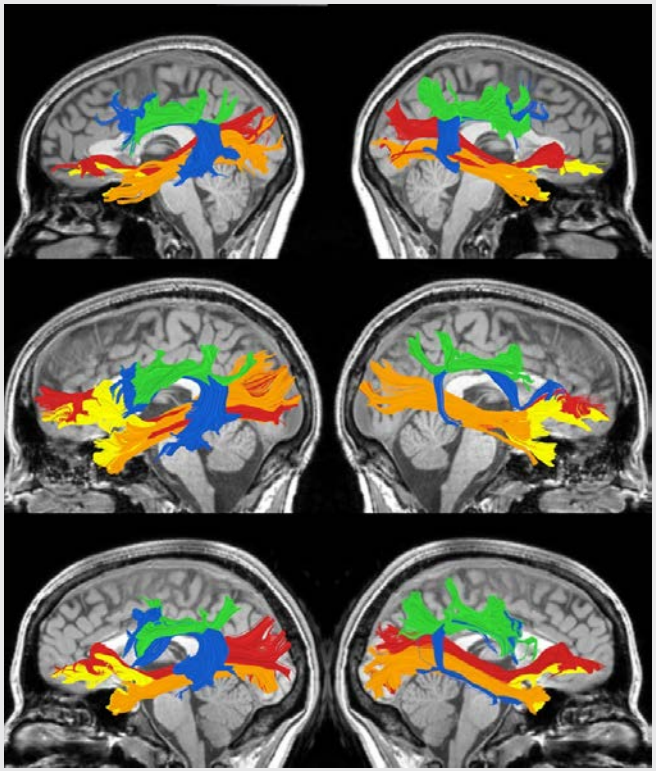
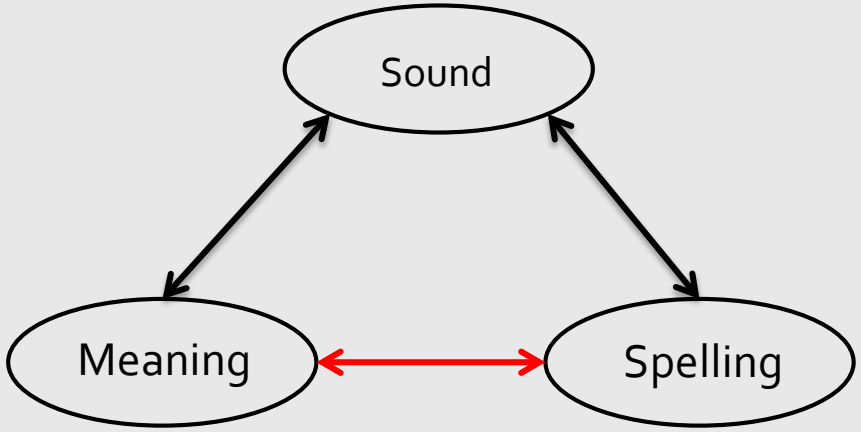
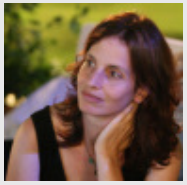
- IFOF
- ILF
- UF

- AF fronto-temporal
- AF fronto-parietal







M. Yablonski & M. Ben-Shachar

Morphology and the ventral pathway

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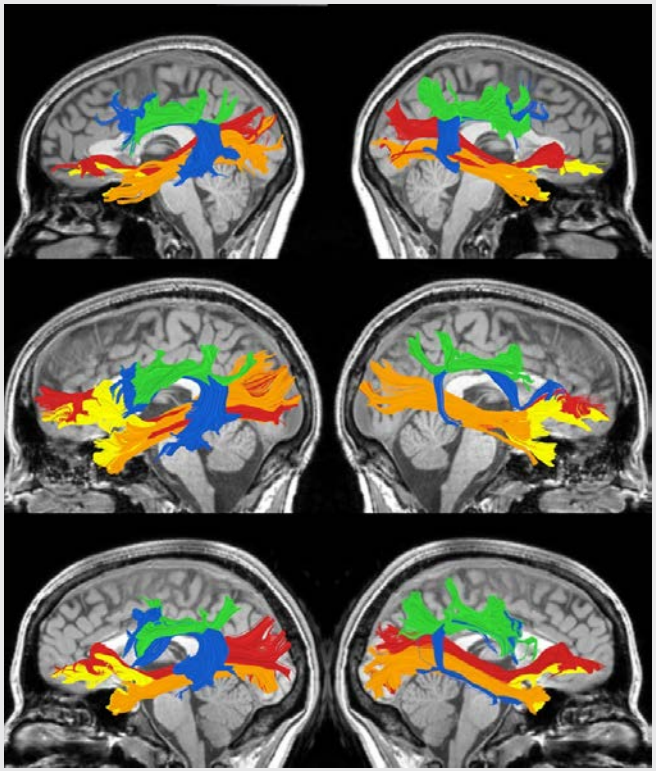
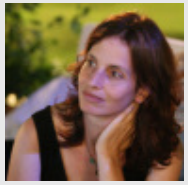
IFOF
ILF
UF

AF fronto-temporal
AF fronto-parietal



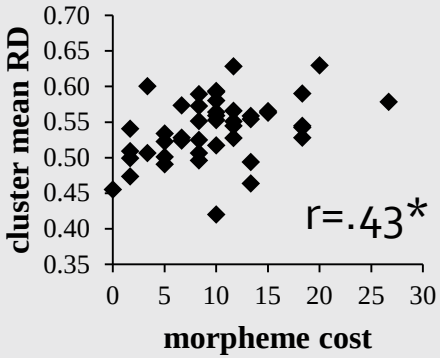
- Behavioural measure of sensitivity to morphemes in reading (N=45)
- Significant correlations with diffusion properties in all **ventral** tracts in left hemisphere; converging evidence from fMRI
- Relationship remains after controlling for phonological processing (nonword repetition)



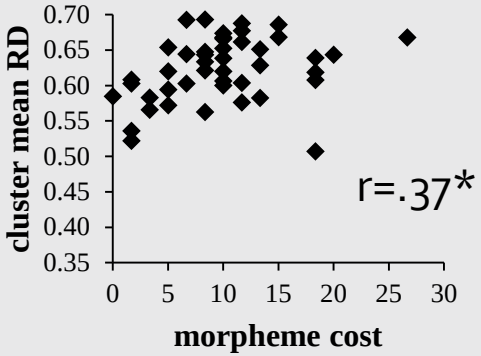
M. Yablonski & M. Ben-Shachar

Morphology and the ventral pathway

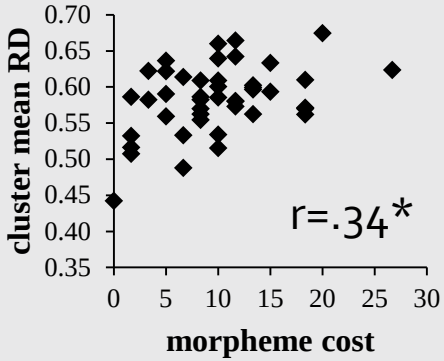
Left IFOF



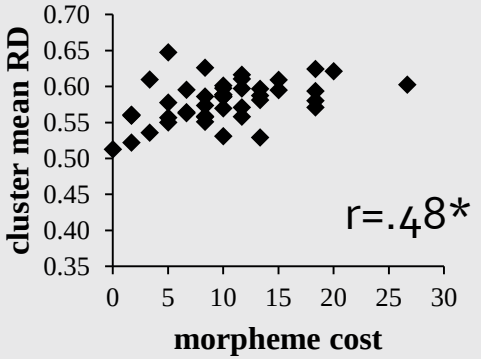
Left ILF



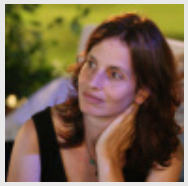
Right IFOF



Left UF



Morphological knowledge is associated with diffusion properties of ventral white matter pathways



M. Yablonski & M. Ben-Shachar

Conclusions

- Properties of writing systems define reading systems; written language is not the same as spoken language; changes to support skilled reading
- English writing comprises spelling-sound and spelling-meaning regularities; spelling-meaning regularities are a consequence of spelling-sound inconsistency
- Spelling-sound knowledge mirrors writing system; represented in dorsal pathway; crucial in reading acquisition but cannot support skilled reading
- Spelling-meaning knowledge mirrors writing system; represented in ventral pathway; crucial for rapid access to meaning from print
- The need for more conversations …

Thanks to the lab …

Davide Crepaldi, Nicola Dawson, Erin Hawkins, Hannah Harvey, Adam Jowett, Maria Ktori, Clare Lally, Rebecca Lucas, Sam McCormick, Marjolein Merkx, Lesley Mitchell, Betty Mousikou, Jakke Tamminen, Jo Taylor, Anastasia Ulicheva, Ivan Yuen

and to collaborators old and new …

and to RHUL Psychology

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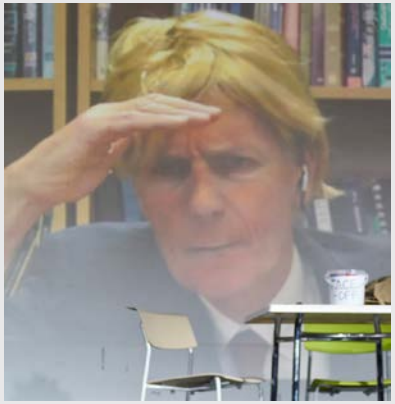
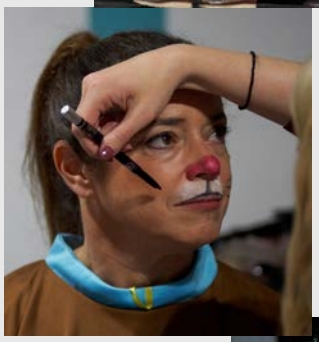
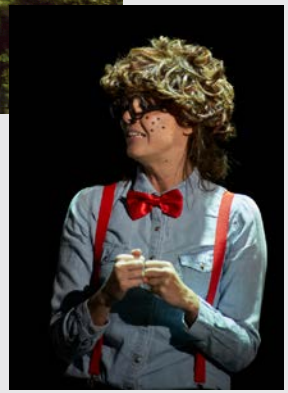
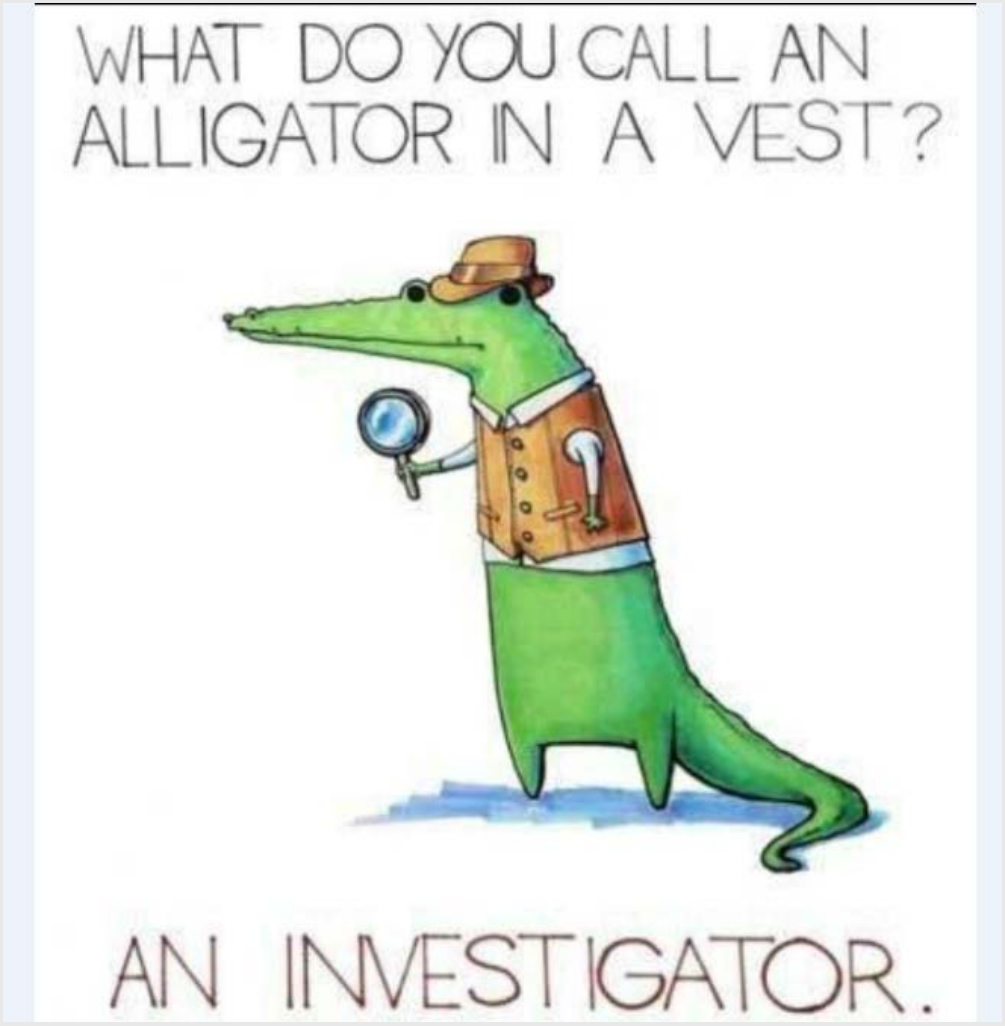






A morphology joke ...



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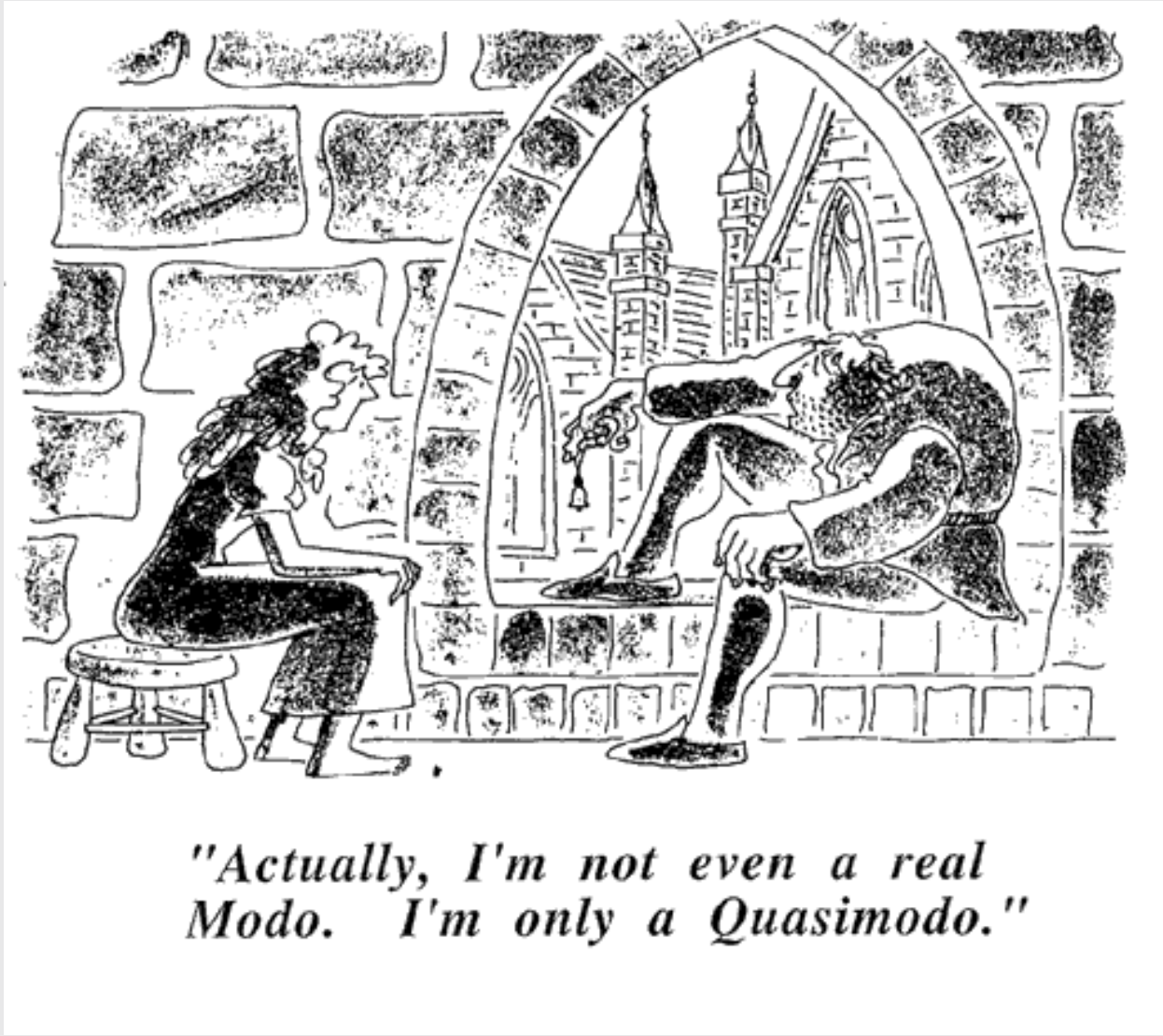

"Actually, I'm not even a real Modo. I'm only a Quasimodo."

Thank you!

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