Click perception by native and non-native click users:

A large-scale web-based perception study

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Introduction

- Clicks: loud and salient but rare and limited in distribution

- How well are clicks perceived by:
  - L1 speakers of **target** click language
  - L1 speakers of **non-target** click language
  - **Click-exposed** non-speakers
  - **Click-naive** non-speakers

Previous click perception studies

	Target	Listeners	Click L1 (target)	Click L1 (non-target)	Click-exposed	Click-naive
Best et al. 1988	Zulu	AmE, Zulu	X			X
Traill 1994	Synthetic	!Xóõ	(X)			
Best et al. 1995	Zulu	AmE infants				X
Best and Avery 1999	Zulu	AmE, Zulu, Xhosa	X	X		X
Best et al. 2003	!Xóõ	AmE, Zulu, Sotho		X		X
Swaminathan and Schellenberg 2017	Zulu	English				X

Previous click perception studies

	Target	Listeners	N
Best et al. 1988	Zulu	AmE, Zulu	9, 14; 40 infants
Traill 1994	Synthetic	!Xóõ	10
Best et al. 1995	Zulu	AmE infants	24 infants
Best and Avery 1999	Zulu	AmE, Zulu, Xhosa	26
Best et al. 2003	!Xóõ	AmE, Zulu, Sotho	42
Swaminathan and Schellenberg 2017	Zulu	English	151

The Perceptual Assimilation model (PAM)

Non-native sounds can be:

1. Assimilated to a native category
2. Assimilated as uncategorizable speech sounds
3. Not assimilated to speech (i.e., perceived as non-speech)

Best (1995, inter alia)

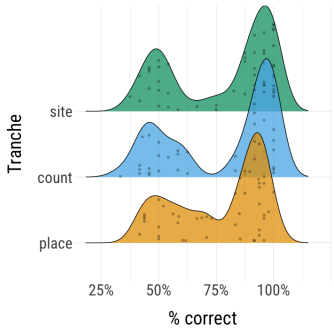
PAM and click-exposed speakers

- Will click-exposed (but not click-native) speakers assimilate clicks as speech sounds or as non-speech sounds?

Speech sounds	Non-speech sounds
↓	↓
Discrimination similar to click-native speakers	Discrimination different from click-native speakers

Our previous studies of click perception

- Two pilots (Zulu clicks; ABX, AXB) where participants scored near chance levels—even native speakers
- AXB task (Zulu clicks) comparing place contrasts vs. count and site contrasts—native speakers scored on average in the 70-80% range, with possible dialect differences



Xhosa's clicks and contrasts

Click type (≈ place)

Accompaniment	Dental		Alveolar		Lateral	
Plain	ǀ (c)	ⁿǀ (nc)	ǃ (q)	ⁿǃ (nq)	ǁ (x)	ⁿǁ (nx)
Breathy-voiced	ǀ̤ (gc)	ⁿǀ̤ (ngc)	ǃ̤ (gq)	ⁿǃ̤ (ngq)	ǁ̤ (gx)	ⁿǁ̤ (ngx)
Aspirated	ǀʰ (ch)		ǃʰ (qh)		ǁʰ (xh)	

The current study

- AXB task
  - Ex: A ~ X ~ B
    ! ~ ! ~ ǁ (c ~ c ~ x) (Ans: A)
    ! ~ ᵑ! ~ ᵑǃ (c ~ nc ~ nc) (Ans: B)
- 56 trials per participant
  - Half CV, half VCV (V = a)
- Online via PsychoPy (Peirce et al. 2022) on Pavlovia.org

Tested contrasts

	Place	Accomp.	IPA	Orthography
Tranche 1 *Place trials*	lateral vs. dental	plain	ǁ ~ !	x ~ c
	dental vs. alveolar	plain	ǀ ~ !	c ~ q
	alveolar vs. lateral	plain	! ~ ǁ	q ~ x
Tranche 2 *Accompaniment trials*	dental	breathy-voiced vs. nasal	ǃ ~ ᵑ!	gc ~ nc
	dental	voiceless vs. nasal	! ~ ᵑ!	c ~ nc
	dental	nasal vs. breathy nasal	ᵑ! ~ ᵑǃ	nc ~ ngc
	dental	breathy-voiced vs. voiceless	ǃ ~ !	gc ~ c

Stimuli

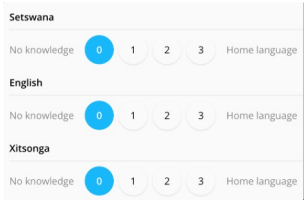
- Produced by Xhosa speaker (M, 20s)
- All H tones
- 56 AXB trials, e.g.
  - ǂa ~ aᵑǂa ~ aᵑǂa (aca ~ anca ~ anca; accompaniment trial)
  - ǂa ~ ǃa ~ ǃa (qa ~ ca ~ ca; place trial)
- 1 second ISI

Procedure

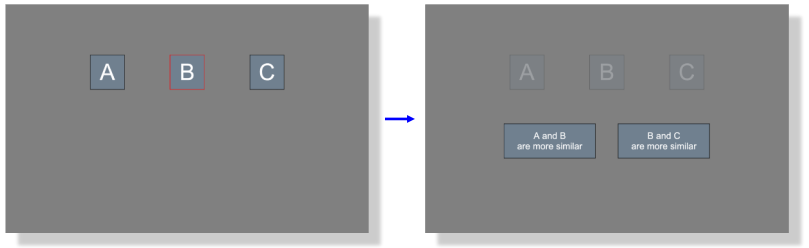
- Demographic survey and consent
- Instructions
- Practice (animal sounds; with feedback)
- Practice (words; with feedback)
- Blocks for CV and VCV (order counterbalanced)
  - Each block contained both place and accompaniment trials, randomized

Demographics

- Age
- Gender
- Which national languages do you know?
- Province where you spent the most time growing up
- Medical issues affecting speech or hearing



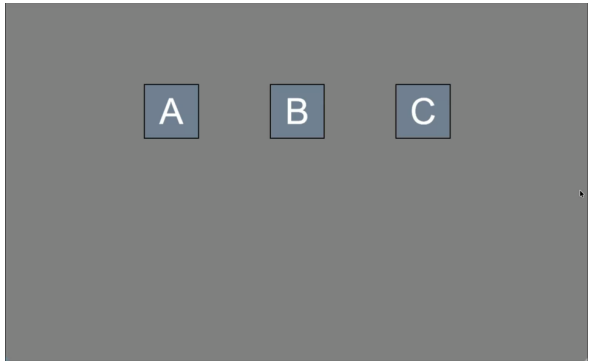
Trials



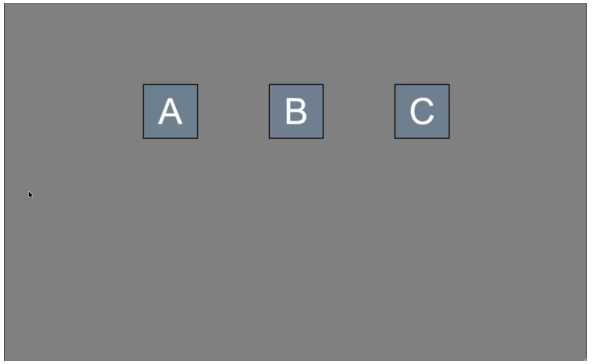
Audio with highlighted boxes

Answer selection

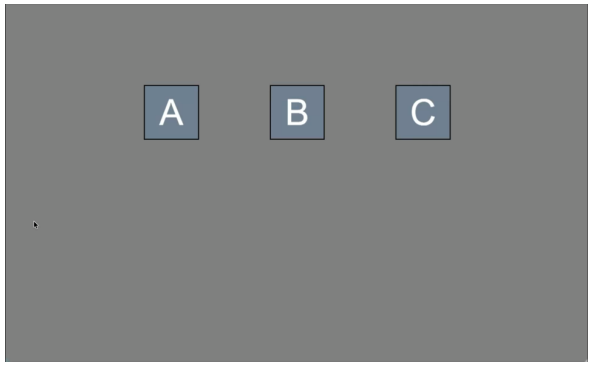
Practice (animal sounds)



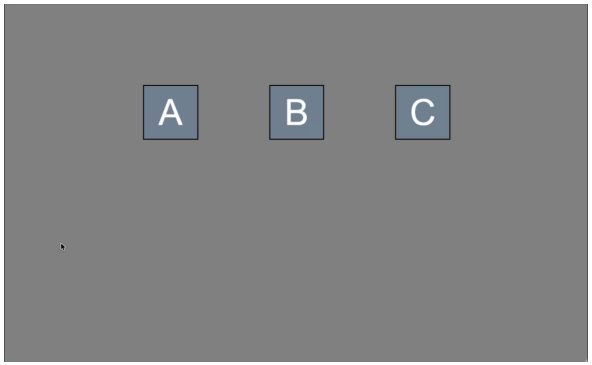
Practice (animal sounds)



Trial (a!a ~ alla ~ alla)

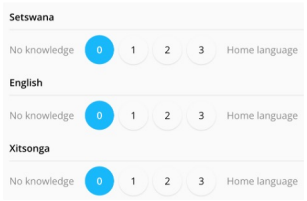


Trial (!a ~ !a ~ la)



Participants

- 274 intro linguistics students at Rhodes University (Makhanda, ZA)
- 186 click-native and 88 click-exposed



Click languages:
isiNdebele, isiXhosa, isiZulu, Sesotho, siSwati

Non-click languages:
Afrikaans, English, Sepedi/Sesotho sa Leboa, Setswana, Tshivenda, Xitsonga, SASL

Participant home languages

Non-click languages		Click languages	
Afrikaans	22	isiNdebele	5
English	95	isiXhosa	135
Sepedi/Sesotho sa Leboa	19	isiZulu	47
Setswana	18	Sesotho	13
Tshivenda	7	siSwati	14
Xitsonga	11		
SASL	8		

Participant home languages

- Very multilingual group
- Self-reported number of home languages:

Languages	Participants
1	152
2	72
3	26
4	1
5	2
6	1

Statistical analysis

- Logistical mixed effects model (on correct/incorrect)
- Fixed factors:
  - Tranche (place vs. accompaniment) and click-nativeness, plus interaction
  - Syllable shape (CV vs. CVC)
  - Correct answer button (A vs. B)
- Random intercepts
  - Participant
  - Item

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glmer(correct ~ tranche * click_native_tri + shape + ab_answer + (1 | participant) + (1 | file) , data = model_data, family = binomial)
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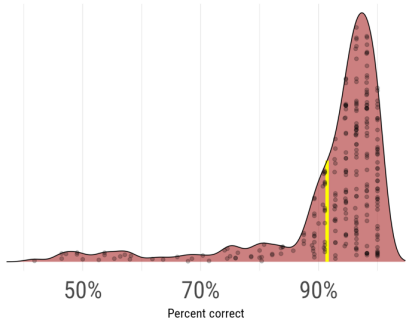
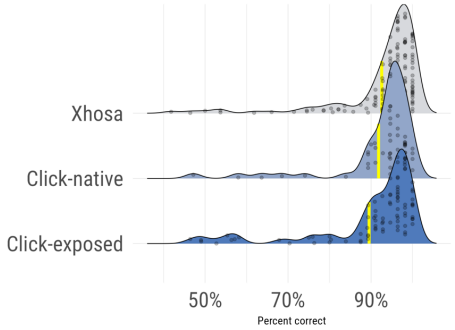
Results

Overall accuracy



Mean	SD
91.45%	11.92

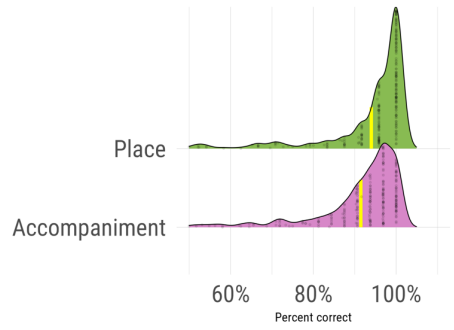
Overall accuracy by click-exposure



	Mean	SD
Xhosa	92.57%	11.14
Click-native	91.81%	10.77
Click-exposed	89.53%	13.48

	β	CI	z	p
click-native	-0.376	[-0.865, 0.113]	-1.508	0.132
click-exposed	-0.519	[-0.926, -0.111]	-2.495	0.013

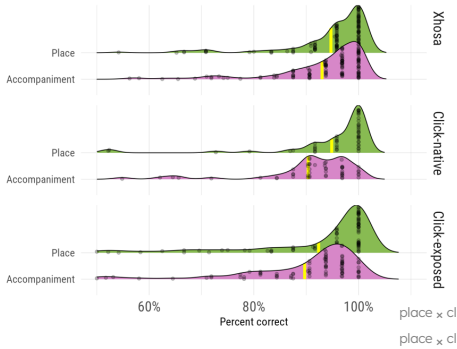
Overall accuracy: Place vs accompaniment trials



	Mean	SD
Place	92.82%	12.92
Accomp.	90.42%	12.22

	β	CI	z	p
tranche [place]	0.216	[-0.069, 0.501]	1.483	0.138

Place vs. accompaniment by click exposure



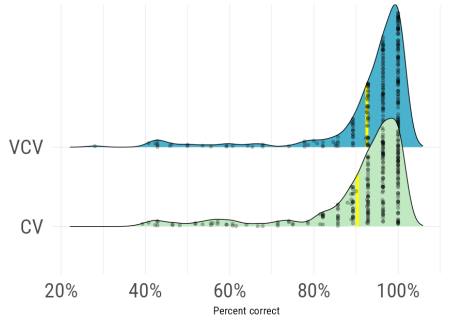
Mean difference: 1.56%

Mean difference: 3.35%

Mean difference: 3.13%

	β	CI	z	p
place x click native	0.309	[-0.065, 0.682]	1.620	0.105
place x click-exposed	0.172	[-0.118, 0.463]	1.163	0.245

Syllable shape



	Mean	SD
VCV	92.60%	12.94
CV	90.34%	13.47

	β	CI	z	p
shape [vcv]	0.318	[0.078, 0.558]	2.59	0.010

Conclusions

- Overall, everyone does fairly well in the task
- Small benefit for more click exposure (Xhosa > Click-exposed; but *not* ~~Xhosa > click-native~~)
- Barely any benefit for place vs. accompaniment, and no real interaction with click exposure
- Large, online perception studies are plausible, even for under-resourced* languages

Moving forward

- How do click-exposed vs. click-naive speakers perform?
  - Upcoming study with American English speakers with no click exposure
- If the task is harder, will we see more separation between groups and conditions?

Thanks!

Download slides:
aaronbraver.com/acal57-perception

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Model table

glmer(correct ~ tranche * click_native_tri + shape + ab_answer + (1 | participant) + (1 | file) , data = model_data, family = binomial)

Parameter	β	CI	z	p
(Intercept)	3.132	[2.791, 3.473]	18.006	0.000
tranche [place]	0.216	[-0.069, 0.501]	1.483	0.138
click native tri [click-exposed]	-0.519	[-0.926, -0.111]	-2.495	0.013
click native tri [click-native]	-0.376	[-0.865, 0.113]	-1.508	0.132
shape [vcv]	0.318	[0.077, 0.558]	2.592	0.010
ab answer [b]	-0.158	[-0.398, 0.082]	-1.289	0.197
tranche [place] × click native tri [click-exposed]	0.172	[-0.118, 0.463]	1.163	0.245
tranche [place] × click native tri [click-native]	0.309	[-0.065, 0.682]	1.620	0.105