Pluralization in the grammar of native speakers: Phonotactics determines singular-plural mapping in Maltese

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Maltese

- Semitic language with characteristics of Maghrebi Arabic, influenced by Sicilian, Italian and English
- National language of Malta, other official language: English
- Spoken by about 400,000 people

Maltese

Plurals

- 2 main strategies to build the plural of a noun:
  Sound Plural: concatenative via suffixation
  annimal – *annimali* 'animal(s)'
  Broken Plural: non-concatenative via internal restructuring of singular stem
  ballun – *blalen* 'ball(s)'
- High amount of variation:
  different sound plural suffixes, between 4 and 39 different broken plural patterns
  bandiera (sg.) *bnadar* (broken pl.) vs. *bandieri* (sound pl.) 'flag'

Maltese Plurals

Predictability

- Is it possible to predict pluralisation of novel words?
- Can novel items be classified as broken or sound plurals?

Previous accounts focus on broken plural prediction only (Farrugia & Rosner, 2008; Drake & Sharp, 2017)

- Farrugia & Rosner (2008): artificial neural network → it did not generalize well to new forms
- Drake & Sharp (2017): different implementations of the Generalized Context Model (Nosofsky, 1990)

→ How to account for the choice of plural forms?

Maltese Plurals

Our work

We are using the Naive Discriminative Learner by Baayen, Milin, Đurđević, Hendrix & Marelli (2011) to predict both, sound and broken plurals

- 3 steps: Data Set - Production Experiment - NDL modeling

Maltese Plurals

Hypothesis

1. The phonotactics of the singular determines the shape of the plural
2. More frequent items are more likely to be generalized than infrequent items

Maltese Experiment

Data Set

- We created a data set of 2369 Maltese nominals
- Words were taken from Schembri (2012) and an online corpus by Gatt & Čéplö (2013)
- Checked with Ġabra: online lexicon for Maltese (Camilleri, 2013)
- CV structure
- Corpus frequency number for each word

Maltese Experiment

Plurals in Data Set

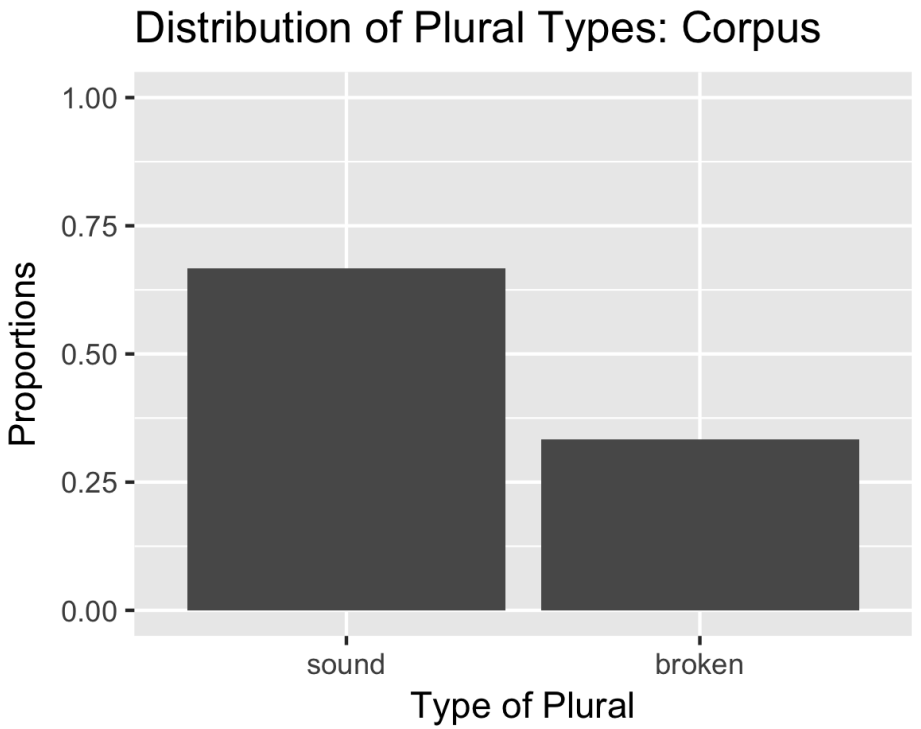


Figure 1: Distribution of Plural Types in our Data Set

Maltese Experiment

Method

- Production task with visual presentation
- Maltese native speakers were asked to produce plural forms for existing Maltese singulars and phonotactically legal nonce singulars (Berko, 1958)
- Nonce forms were constructed from words of our data set of 2369 Maltese nominals by changing either the consonants or the vowels or both systematically, e.g.: *sema* ‚sky', $\rightarrow$ *fera soma fora*
- The results are three lists of wug words: C, V, CV
- The words of our data set used as base had either a sound plural form, a broken plural form or both plural forms: SP, BP, BOTH

Maltese Experiment

Stimuli

We chose **90 nonce words**:

- 30 from list C
  - 10 Base Broken Plural
  - 10 Base Sound Plural
  - 10 Base Both
- 30 from list V
  - 10 Base Broken Plural
  - 10 Base Sound Plural
  - 10 Base Both
- 30 from list CV
  - 10 Base Broken Plural
  - 10 Base Sound Plural
  - 10 Base Both

And **22 existing nouns**:

- 5 frequent sound plural words, 5 infrequent sound plural words
- 5 frequent broken plural words, 5 infrequent broken plural words
- 2 training items (1 sound plural, 1 broken plural)

Maltese Experiment

Results - List

glmer with lme4 package (Bates, Mächler, Bolker & Walker, 2015)

- dependent variable:
  Answers of participants (binary, Sound or Broken Plural)
- independent variables:
  List = C, V, CV
  Base =SP, BP, BOTH
- random effects:
  Singular, Speaker

Maltese Experiment

Results - List

Does the change of consonants, vowels or both to build nonce words have an effect on the produced plural type of the nonce words?

Maltese Experiment

Results - List

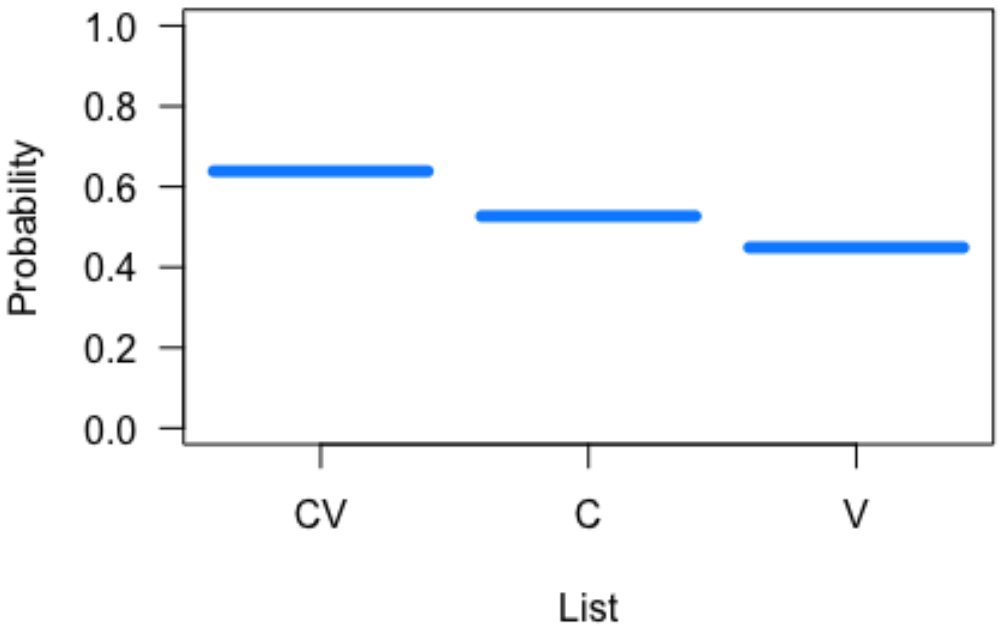


Figure 2: Results of glmer model with variable: List

Significant difference between List CV and List V ($p<0.001$)

Maltese Experiment

Results - Base

Does the plural form of the existing word that has been used as a base for the nonce word have an effect on the produced plural type of the nonce words?

Maltese Experiment

Results - Base

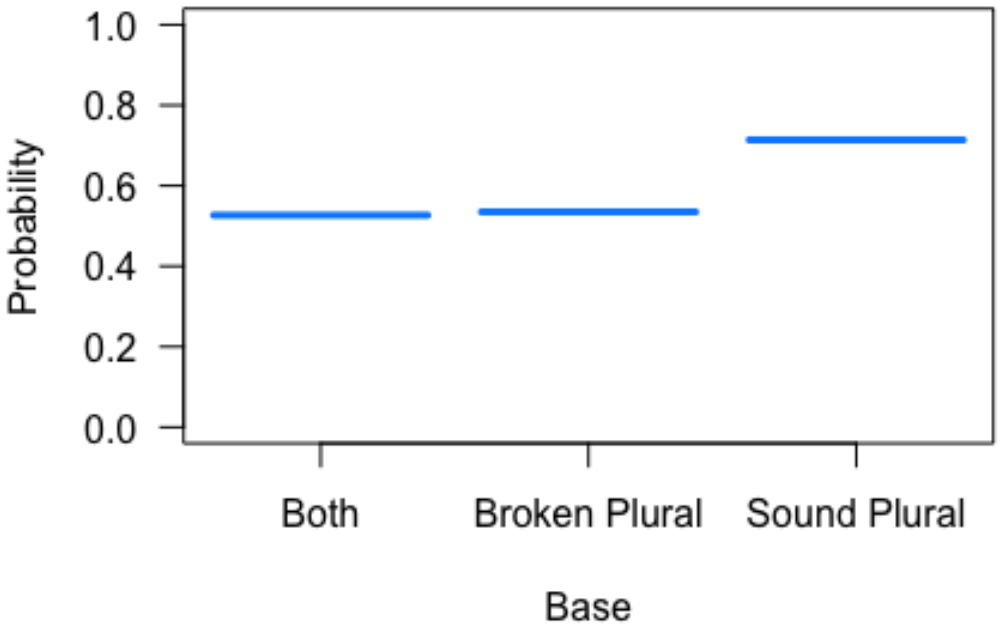
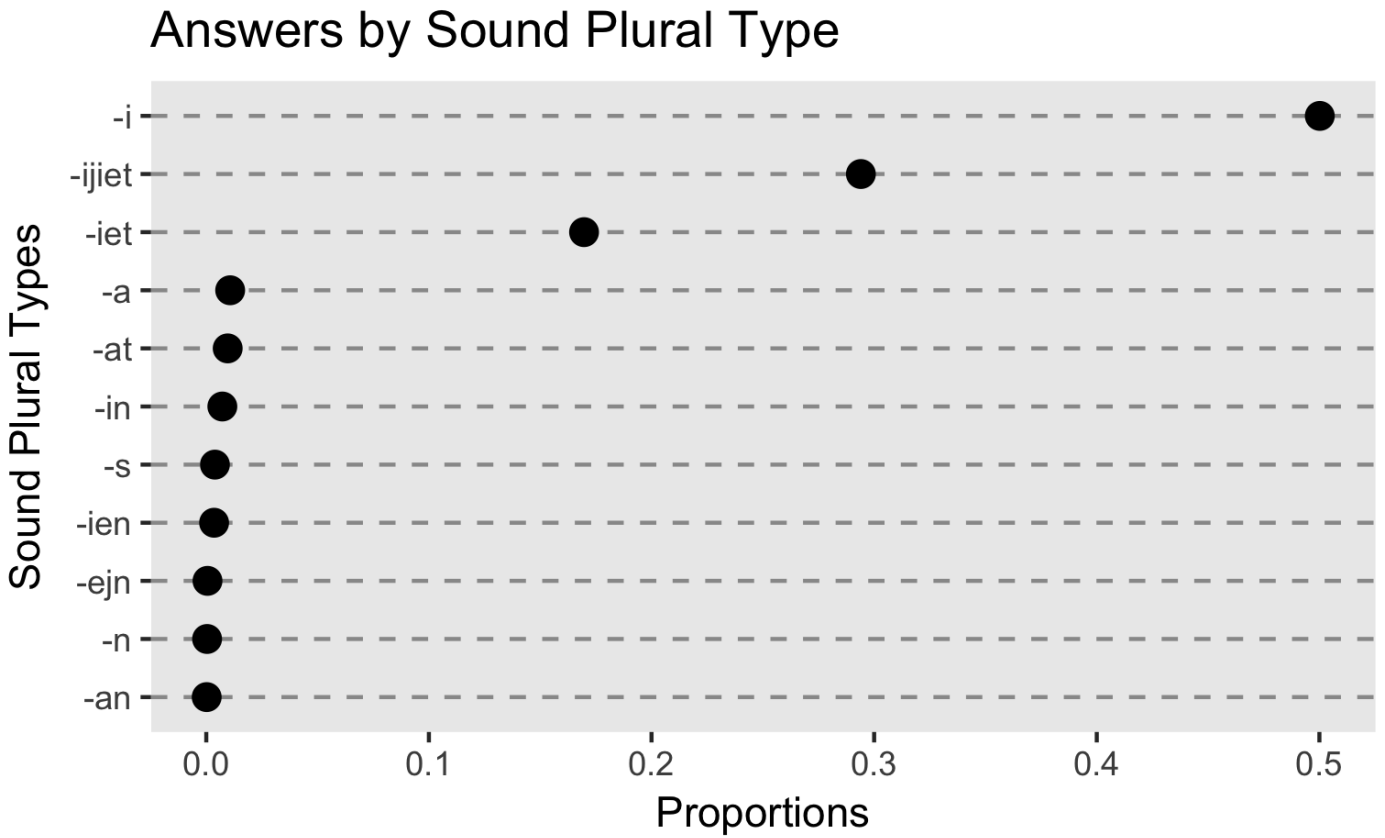


Figure 3: Results of glmer model with variable: Base

Significant difference between Base Broken and Base Sound ($p<0.001$)

Maltese Experiment

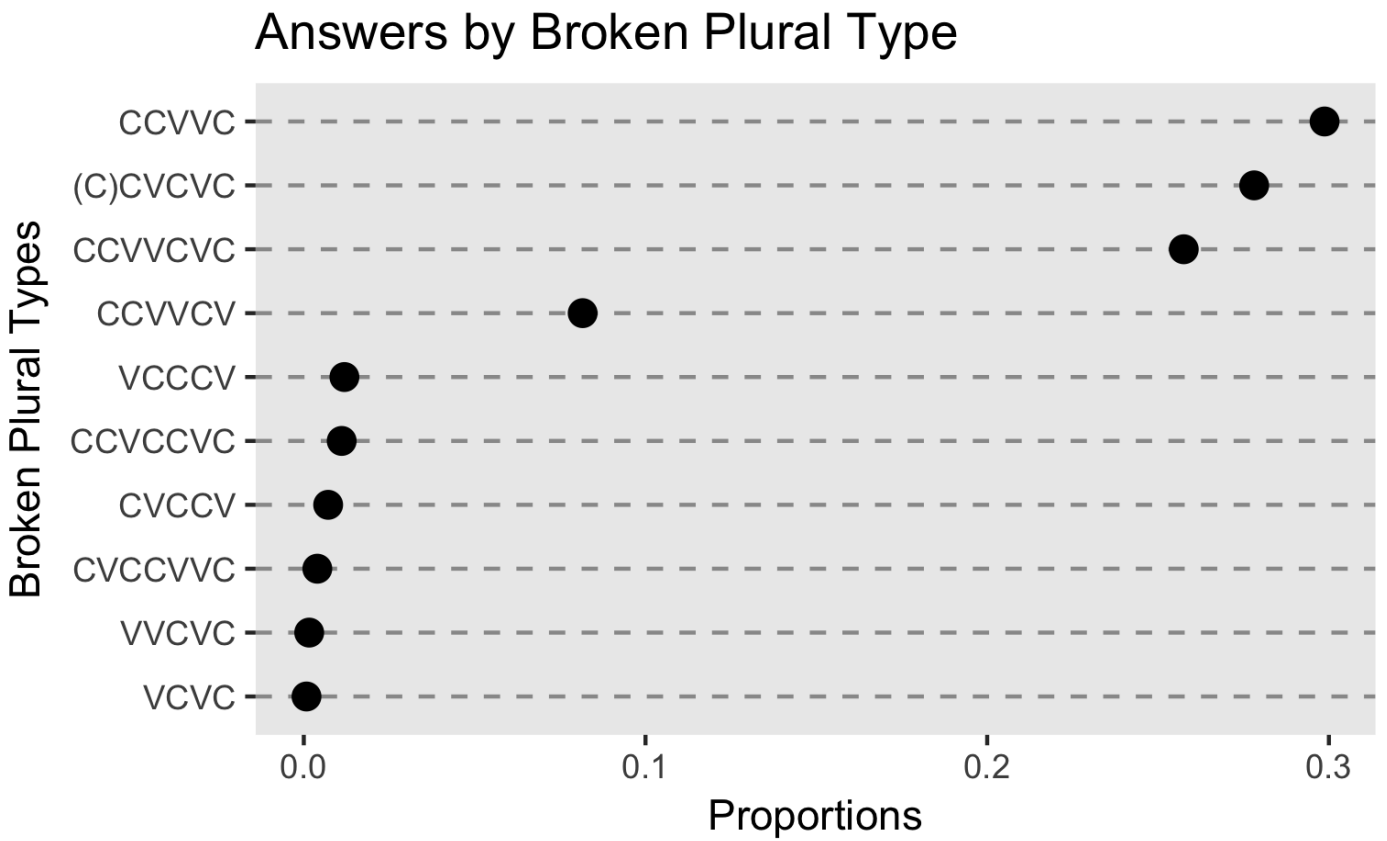
Results - Sound Plurals



- *-i* and *-ijiet* are the most common suffixes in our data set, too

Maltese Experiment

Results - Broken Plurals



- According to Schembri (2012) the patterns CCVVC, (C)CVCVC and CCVVCVC are highly productive in Maltese

Maltese Experiment

Results - Existing Words

	frequent	infrequent
sound	5/400; 1.3%	14/400; 3.5%
broken	1/400; 0.3%	177/400; 44.3%

Table 1: Proportion of pluralization errors for existing singular nouns

- Error = Non-canonical plural forms = forms we do not find in the dictionary

Summary: Results so far

- Changing consonants and vowels influenced the choice of plural forms
- The plural form of the existing word used as base for nonce words influenced the choice of plural
- Participants produced broken plurals for nonce words with the most frequent CV structure, sound plurals for nonce words with most common suffixes

Naive Discriminative Learning

Baayen (2011), Baayen et al. (2011)

- Cognitive two-layer network
- NDL simulates a learning process
- Supervised learning
- Has been used successfully to model language acquisition (Ramscar, Yarlett, Dye, Denny & Thorpe, 2010)
- Central idea: learning = exploring how events are inter-related, they become associated (Plag & Balling, 2016)
- inter-related events: *Cues* and *Outcomes*

Naive Discriminative Learning

Baayen (2011), Baayen et al. (2011)

- Based on Rescorla-Wagner equations that are well established in cognitive psychology (Rescorla & Wagner, 1972)
- Associations between cues and outcomes at a given time, whereas the strength of an association, the association weight, is defined as follows (Evert & Arppe, 2015):
  - No change if a cue is not present in the input
  - Increased if the cue and outcome co-occur
  - Decreased if the cue occurs without the outcome
- Danks (2003) equilibrium equations: define association strength when a stable state is reached = „adult state of the learner“ (Baayen, 2011)
- Implementation as R package *ndl*

Naive Discriminative Learning

Baayen (2011), Baayen et al. (2011)

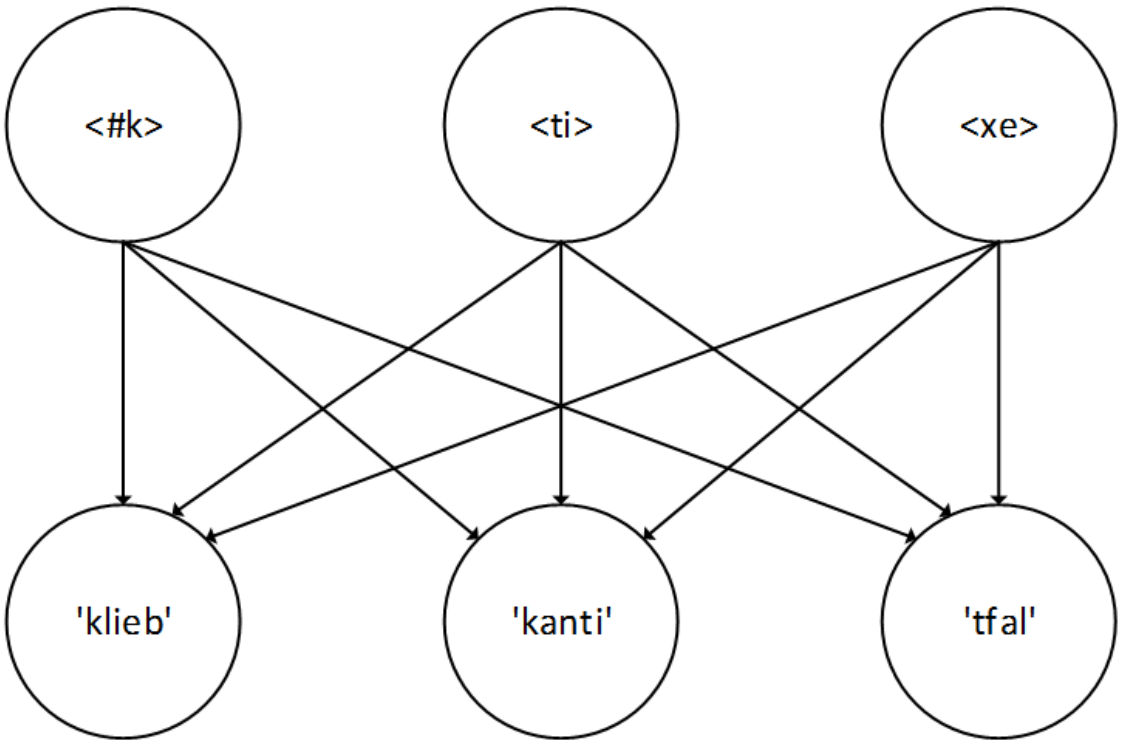


Figure 4: Association between Cues and Outcomes

Modeling our Data: Naive Discriminative Learning

- We trained the NDL model on our corpus
- We formulated our singular items in n-grams (unigrams, bigrams, trigrams) and calculated how the NDL learner would classify them

Singulars	Cues	Outcomes
qassis 'priest'	#q_qa_as_ss_si_is_s#	sound plural
tokka 'pen'	#t_to_ok_kk_ka_a#	broken plural

Table 2: Training data set for the NDL model using bigrams as cues

Modeling our Data: Naive Discriminative Learning

- The associations between cue and outcome are weighted
- We used NDL to predict classification of existing singular forms and nonce words

Cue	Broken Plural	Sound Plural
#k	−0.12	0.62
ke	0.42	−0.42
el	0.17	−0.17
lb	0.17	−0.16
b#	0.42	0.07
sum	1.06	−0.06

Table 3: Example for NDL association weights predicting outcome „broken“ for singular *kelb*

Modeling our Data: Naive Discriminative Learning

- We compared the classification of participants with the prediction of different cue implementations in NDL
- What implementation best models the intuitions of native speakers on plural formation in Maltese?

Modeling our Data: Naive Discriminative Learning

Results - Unigrams as Cues

example: kelb = k_e_l_b 'dog'

	broken	sound
broken	0.08	0.92
sound	0.05	0.95

Table 4: Classification of experimental items by NDL using unigrams as cues

- Very good prediction for sound plurals
- Very poor prediction for broken plurals

Modeling our Data: Naive Discriminative Learning

Results - Bigrams as Cues

example: kelb = #k_ke_el_lb_b# 'dog'

	broken	sound
broken	0.59	0.41
sound	0.33	0.67

Table 5: Classification of experimental items by NDL using bigrams as cues

- Acceptable prediction for both plural types

Modeling our Data: Naive Discriminative Learning

Results - Trigrams as Cues

example: kelb = #ke_kel_elb_lb# 'dog'

	broken	sound
broken	0.66	0.34
sound	0.52	0.48

Table 6: Classification of experimental items by NDL using trigrams as cues

- Good prediction for broken plurals
- Prediction for sound plurals are chance

Results

Discussion

- Trigrams are the best predictors for broken plurals – unigrams the worst
- Unigrams are the best predictors for sound plurals – trigrams the worst
- Participants used sound plurals more often and corpus contains more sound plurals: when predicting plural forms with just one element of a word (=unigrams), sound plurals will be the default
- Phonotactics (trigrams $\approx$ syllables) is especially important for broken plural predictions

- glmer model indicates that changing consonants and vowels influenced the choice of plural forms
- Can the NDL model capture this?
- How important are consonants and vowels for the NDL model?
- We changed vowels in cues to V, consonants to C to delete vowel and consonant identity:
  barma 'twist' = #b_bV_Vr_rm_mV_V#
  barma 'twist' = #C_Ca_aC_CC_Ca_a#

Results

Vowel as V

		broken	sound
unigrams	broken	0.13	0.87
	sound	0.06	0.94
bigrams	broken	0.39	0.61
	sound	0.25	0.75
trigrams	broken	0.49	0.51
	sound	0.42	0.58

Table 7: NDL models with vowels in cues changed to "V"

Results

Consonants as C

		broken	sound
bigrams	broken	0.17	0.83
	sound	0.06	0.94
trigrams	broken	0.02	0.98
	sound	0.02	0.98

Table 8: NDL models with consonants in cues changed to "C"

- When all consonants of the experimental items are changed to C we find very poor predictions for broken plurals, regardless of the size of gram
  - Consonants are slightly more important for generalization of broken plurals!
- When all vowels of the experimental items are changed to V we find a slightly better performance for broken plurals (especially with bigrams and trigrams), nevertheless we cannot replicate the good results of our NDL model 2
  - An abstract representation of consonants and vowels makes the NDL model worse

Results

Discussion

- Let's compare our results with other models that have been used with Arabic broken plural nouns:
- Our best NDL model: 65.3%
- Pierrehumbert (2002) used modified versions of the Generalised Context Model (Nakisa, Plunkett & Hahn, 2001; Albright & Hayes, Albright & Hayes): Accuracy of the models ranged between 55.31 – 65.97%

→ Is it possible to predict pluralisation of novel words?

→ Can novel items be classified as broken or sound plurals?

- Native speakers are able to generalize to novel nouns and use the most common suffixes and CV patterns for this task

- Consonants and vowels are important for the generalizations of Maltese plurals as
  - changing consonants and vowels influenced the choice of plural form of participants and
  - using abstract representations influenced the performance of the NDL models.
- Phonotactics of the singular determines the plural form

Grazzi ħafna!

References I

Albright, A. & Hayes, B. Rules vs. analogy in english past tenses: a computational/experimental study. *90*(2), 119–161.

Baayen, H. R. (2011). Corpus linguistics and naive discriminative learning. *Brazilian Journal of Applied Linguistics*, *11*, 295–328.

Baayen, R. H., Milin, P., Đurđević, D. F., Hendrix, P., & Marelli, M. (2011). An amorphous model for morphological processing in visual comprehension based on naive discriminative learning. *Psychological Review*, *118*(3), 438–481.

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*(1).

Berko, J. (1958). The child's learning of english morphology. *WORD*, *14*(2), 150–177.

Camilleri, J. J. (2013). A computational grammar and lexicon for maltese. Master thesis, University of Gothenburg.

References II

Danks, D. (2003). Equilibria of the rescorla-wagner model. *Journal of Mathematical Psychology*, *47*, 109–121.

Drake, S. & Sharp, R. (2017). Productivity of the broken plural in maltese. In *6th International Conference of Maltese Linguistics*.

Evert, S. & Arppe, A. (2015). Some theoretical and experimental observations on naïve discriminative learning. In *Proceedings of the 6th Conference on Quantitative Investigations in Theoretical Linguistics (QITL-6)*, Tübingen, Germany.

Farrugia, A. & Rosner, M. (2008). Maltimorph, a computational analysis of the maltese broken plural. *Proceedings of Workshop on ICT 2008*.

Gatt, A. & Čéplö, S. (2013). Digital corpora and other electronic resources for maltese. In *Proceedings of the International Conference on Corpus Linguistics*. Lancaster, UK: University of Lancaster.

References III

Nakisa, R., Plunkett, K., & Hahn, U. (2001). Single- and dual- route models of inflectional morphology. In P. Broeder & J. Murre (Eds.), *Models of language acquisition: Inductive and deductive approaches* (pp. 201–222). Cambridge, MA: MIT Press.

Nosofsky, R. (1990). Relations between exemplar-similarity and likelihood models of classification. *Journal of Mathematical Psychology*.

Pierrehumbert, J. B. (2002). Probabilistic phonology: Discrimination and robustness.

Plag, I. & Balling, L. W. (2016). Derivational morphology: An integrative perspective on some fundamental issues. In V. Pirelli, I. Plag, & W. U. Dressler (Eds.), *Word knowledge and word usage: A cross-disciplinary guide to the mental lexicon*. Berlin, New York: De Gruyter.

Ramscar, M., Yarlett, D., Dye, M., Denny, K., & Thorpe, K. (2010). The effects of feature-label-order and their implications for symbolic learning. *Cognitive Science*, *34*(6), 909–957.

References IV

Rescorla, R. & Wagner, A. (1972). A theory of pavlovian conditioning: variations in the effectiveness of reinforcement and nonreinforcement. In A. Black & W. Prokasy (Eds.), *Classical conditioning II: current research and theory* (pp. 64–99). New York: Appleton-Century-Crofts.

Schembri, T. (2012). *The Broken Plural in Maltese: A Description*. Il-Lingwa Tagħna. Univ.-Verl. Brockmeyer.

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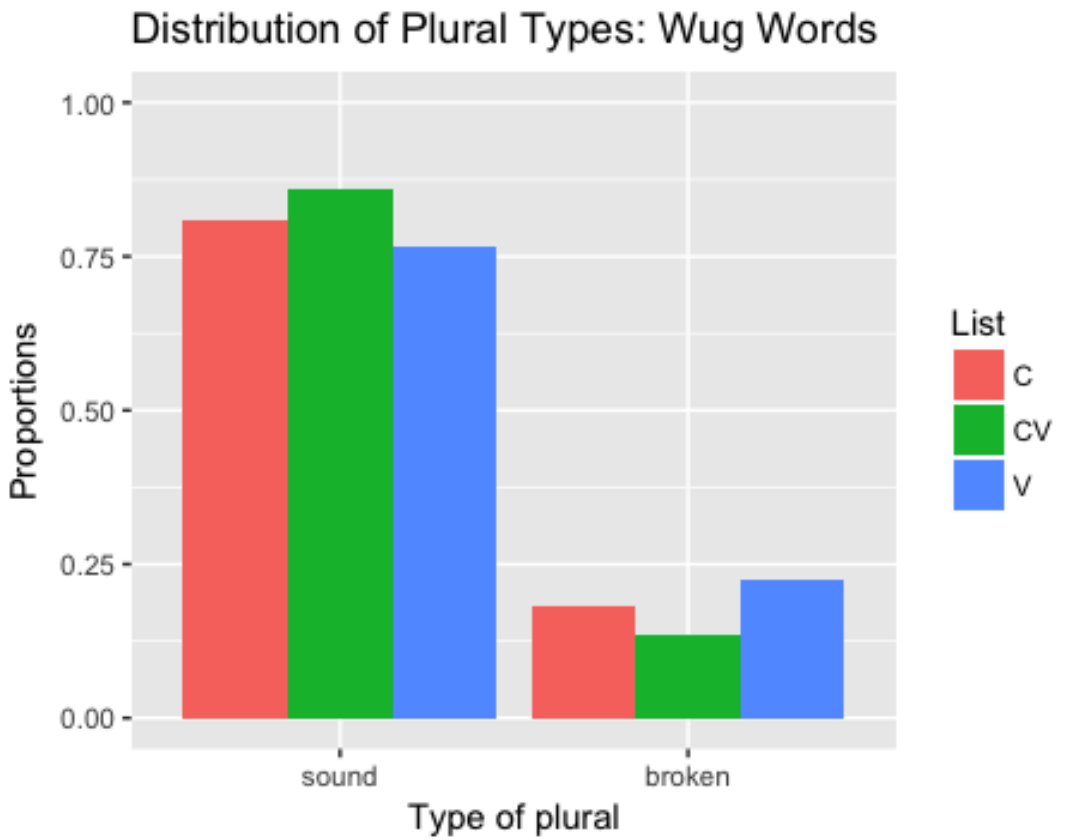
Extras



In total:
5404 sound plural answers for wug words only
(6387 for wugs + existing words)
1262 broken plural answers for wug words only
(1986 for wugs + existing words)