Maltese Plurals: Evidence from a Nonce Word Experiment

Jessica Nieder & Ruben van de Vijver

nieder@phil.hhu.de Ruben.Vijver@hhu.de

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Maltese Plurals

• 2 main strategies to build the plural of a noun:
  - **Sound Plural** `sptar` – `sptarijiet` ‘hospital(s)’
  - **Broken Plural** `ballun` – `blalen` ‘ball(s)’

• There is variation within the two different plural forms:
  - a number of sound plural suffixes, between 4 and 39 different broken plural patterns

• There is also variation in the choice of the plural forms:
  - `bandiera` (sg.) `bnadar` (broken pl.) vs. `bandieri` (sound pl.) ‘flag’
Maltese Plurals: Learnability

• Is it possible to predict pluralisation of novel words?
• If there are no rules governing the plural formation (Sutcliffe, 1924 cited in Schembri, 2012), this means that there is no – linguistic or statistical – structure in the data that allows native speakers to generalize
Maltese Plurals: Previous accounts

**Prosodic Morphology** (McCarthy & Prince, 1990a, 1990b, 1994)
Plural forms are mapped on prosodic templates or shape-invariant patterns

• What happens in a system that shows a lot of variation?
• We find marked prosodic patterns: CCVV
• How to account for these patterns?
• Dawdy-Hesterberg & Pierrehumbert (2014):
  ➢ Ernestus & Baayen (2003) have shown that phonological features play a role for morphological generalization
Maltese Plurals: Previous accounts

CV-skeleton mapping
Has been used as description of different broken plural types in Maltese (e.g. Schembri, 2012)

• How to account for sound plural forms?
• What skeletons trigger choice of plural forms?
Maltese Plurals: Previous accounts

• Common idea of these accounts: the phonotactics of the singular determines the shape of the (broken) plural

➢ good starting point
Maltese Plurals: Hypothesis

• The phonotactics of the singular determines the shape of the plural
• More frequent items are more likely to be generalized than infrequent items.
Maltese Plurals: Our work

➢ To test the hypotheses we created a corpus and conducted a production experiment

➢ We modeled our experimental data with the Naive Discriminative Learner, a cognitive learning algorithm (Baayen et al., 2011) that does not rely on abstract representations like CV-structure: are generalizations possible?
Maltese Experiment: Corpus

- We created a corpus of 2369 Maltese nominals
- Words were taken from Schembri (2012) and an online corpus (MLRS Corpus Malti v. 2.0)
- Checked with Ġabra: online lexicon for Maltese (Camilleri, 2013)
- CV structure
- Corpus frequency number for each word
Maltese Experiment: Plurals in Corpus

Distribution of Plural Types: Corpus

Type of Plural

- sound
- broken

Proportions

- 1.00
- 0.75
- 0.50
- 0.25
- 0.00
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-Gleason, 1958)
  
  • Nonce forms were constructed from words of our corpus of 2369 Maltese nominals by changing either the consonants or the vowels or both systematically, e.g.: \( \text{sema 'sky'} \rightarrow \text{fera} \quad \text{soma fora} \)

• The results are three lists of wug words: C, V, CV

• The words of our corpus 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: Procedure

• Participants: 80 adult native speakers of Maltese: 50 female, 30 male (mean age 24.6), recruited at the University of Malta
• We recorded the plural answers of the participants
Maltese Experiment: Procedure

Randomized order of stimuli

Training phase: adjustment of settings

- *Dik l-istampa ta’ kelb*
- *Dik l-istampa ta’ kappella*
- *Hafna_________*
- *Hafna_________*

Read instructions

Test phase: recording of 4000 milliseconds

- *Dik l-istampa ta’ ħomka*
- *Hafna_________*
Maltese Experiment: Results - Variation

<table>
<thead>
<tr>
<th>Nonce Singular</th>
<th>Speaker A</th>
<th>Speaker B</th>
<th>Speaker C</th>
<th>Speaker D</th>
</tr>
</thead>
<tbody>
<tr>
<td>xogol</td>
<td>xgiegel</td>
<td>xogolijiet</td>
<td>xogliet</td>
<td>xogoli</td>
</tr>
<tr>
<td>tolluq</td>
<td>tlielaq</td>
<td>tolluqijiet</td>
<td>tlieqi</td>
<td>tolluqi</td>
</tr>
<tr>
<td>żepelp</td>
<td>żepelpijiet</td>
<td>żepelpi</td>
<td>żpiepel</td>
<td>żepelpi</td>
</tr>
<tr>
<td>follu</td>
<td>folol</td>
<td>folli</td>
<td>follijiet</td>
<td>folliet</td>
</tr>
</tbody>
</table>

- There is a lot of variation in our data: different plural forms per item (broken plural, sound plural)
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

Distribution of Plural Types: Wug Words

Type of plural

Proportions

List
- C
- CV
- V

sound

broken
Maltese Experiment: Results – List

glmer with lme4 package (Bates, Maechler, 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

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

Answers by Base of the Nonce Words

- BOTH
- BP
- SP

Answers Participants

Base
Maltese Experiment: Results - Base

Significant difference between Base Broken and Base Sound ($p<0.001$)
Maltese Experiment: Results – Sound Plurals

Answers by Sound Plural Type

Sound Plural Types
- -i
- -ijiet
- -iet
- -a
- -at
- -in
- -s
- -ien
- -ejn
- -n
- -an

Proportions
Maltese Experiment: Results – Sound Plurals

• -i and –ijiet are the most common suffixes in our corpus, too
• One participant of the experiment said

„When we [=the Maltese native speakers] do not know the word, we just put an –i or –ijiet on it. That will leave the word as it is and we avoid mistakes.“
Maltese Experiment: Results – Broken Plurals

Answers by Broken Plural Type

Broken Plural Types

- CCVVC
- (C)CVVC
- CCVVCC
- CCVV
- VCCVC
- CCVCVC
- CVCCVC
- CVCC
- CVCCVC
- VVCVC
- VCVC

Proportions
Maltese Experiment: Results – Broken Plurals

• Most frequent broken plural patterns in our data:

<table>
<thead>
<tr>
<th>patterns</th>
<th>wug words (sg.-pl.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCVVC</td>
<td><em>telleb</em> – <em>tlieb</em></td>
</tr>
<tr>
<td>CCVVCVC</td>
<td><em>peţna</em> - <em>pţieţen</em></td>
</tr>
<tr>
<td>CVCVC</td>
<td><em>baċċa</em> - <em>bačeċ</em></td>
</tr>
</tbody>
</table>

• According to Schembri (2012) these patterns are highly productive in Maltese
Maltese Experiment: Results – Existing Words

<table>
<thead>
<tr>
<th>Non-canonical frequent</th>
<th>Non-canonical infrequent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sound</td>
<td>Broken</td>
</tr>
<tr>
<td>5 (of 400)</td>
<td>1 (of 400)</td>
</tr>
<tr>
<td>1,3%</td>
<td>0,3%</td>
</tr>
<tr>
<td>Sound</td>
<td>Broken</td>
</tr>
<tr>
<td>14 (of 400)</td>
<td>177 (of 400)</td>
</tr>
<tr>
<td>3,5%</td>
<td>44,3%</td>
</tr>
</tbody>
</table>

Table: Proportion of non-canonical plural forms for existing singular nouns

- 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)

• Computational model of morphological processing
• 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 (see also 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: Association between Cues and Outcomes
Modeling our Data: Naive Discriminative Learning

• We trained the NDL model on our corpus
• We formulated our singular nonce words in bigrams and calculated how the NDL learner would classify them
  
  ➢ Cues: singulars in bigrams, #k – ke - el - lb - b#  
  ➢ Outcome: plural types, #k → sound, ke → broken...

• The associations between cue and outcome are weighted  
• We used NDL to predict classification of nonce words
## Modeling our Data: Naive Discriminative Learning

<table>
<thead>
<tr>
<th>Cue</th>
<th>Broken Plural</th>
<th>Sound Plural</th>
</tr>
</thead>
<tbody>
<tr>
<td>#k</td>
<td>-0.1228488034</td>
<td>0.6212695562</td>
</tr>
<tr>
<td>ke</td>
<td>0.4219441264</td>
<td>-0.4219441264</td>
</tr>
<tr>
<td>el</td>
<td>0.1686745205</td>
<td>-0.1690560897</td>
</tr>
<tr>
<td>lb</td>
<td>0.1667921396</td>
<td>-0.1638825484</td>
</tr>
<tr>
<td>b#</td>
<td>0.4240803967</td>
<td>0.0749708285</td>
</tr>
<tr>
<td>sum</td>
<td>1,05864238</td>
<td>-0.05864238</td>
</tr>
</tbody>
</table>

Table: Example for NDL association weights predicting outcome „broken“ for singular *kelb*
Modeling our Data: Naive Discriminative Learning – Results

- We compared the classification of participants with NDL
- NDL correctly classified 65.3 % of our observations

<table>
<thead>
<tr>
<th></th>
<th>broken</th>
<th>sound</th>
</tr>
</thead>
<tbody>
<tr>
<td>broken</td>
<td>0.6045667</td>
<td>0.3954333</td>
</tr>
<tr>
<td>sound</td>
<td>0.3319242</td>
<td>0.6680758</td>
</tr>
</tbody>
</table>

Table: Classification of nonce words by NDL
Modeling our Data: Naive Discriminative Learning

• Let’s compare our results with other models that have been used with Arabic broken plural nouns:


  ➢ Accuracy of the models ranged between 55.31 – 65.97%

  ➢ Our NDL analysis: 65.3%
Discussion

• There is structure in our data

• Native speakers are able to inflect novel nouns

• Participants produced more broken plural words when we just changed the vowels of existing singulars to create nonce words
  ➢ When both, consonants and vowels, were changed, participants produced the highest number of sound plural forms
  ➢ Consonants and vowels are important for the generalizations of broken plurals ➔ evidence for tier separation

• Phonotactics of the singular determines the plural form

• Plurals are generalizable!

• (And, as always: much work still needs to be done.)
Grazzi ħafna!
References


Rescorla-Wagner equations
Baayen et al. (2011)

The Rescorla-Wagner equations specify the association strength $V_{i}^{t+1}$ of cue $C_{i}$ with outcome $O$ at time $t + 1$ as

$$V_{i}^{t+1} = V_{i}^{t} + ΔV_{i}^{t},$$

with the change in association strength $ΔV_{i}^{t}$ defined as:

$$ΔV_{i}^{t} = \begin{cases} 
0 & \text{if ABSENT}(C_{i}, t) \\
α_{i}β_{1} \left( \lambda - \sum_{\text{PRESENT}(C_{j}, t)} V_{j} \right) & \text{if PRESENT}(C_{j}, t) & \& \text{PRESENT}(O, t) \\
α_{i}β_{2} \left( 0 - \sum_{\text{PRESENT}(C_{j}, t)} V_{j} \right) & \text{if PRESENT}(C_{j}, t) & \& \text{ABSENT}(O, t) 
\end{cases}$$