Analogy in the Plural System of Maltese

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Maltese
Maltese

- It is a semitic language, with characteristics of Maghrebi Arabic and traces of Levantine Arabic.
- National language of Malta.
- Spoken by about 400.000 people in Malta (Malta, Gozo and 1 family in Comino).
- Another 100.000 people speak it around the world (Australia, the US, Canada, Belgium, Luxembourg, Italy and the UK.)
Maltese

- It has been influenced by Italian (Sicilian) and English.
- The lexicon consists of 32% Arabic, 52% Italian and 6% English items. (And a rest of obscure origin (Brincat, 1996).)
  - ḥabib 'friend'
  - furketta 'fork'
  - xawer 'shower'
- The Arabic words are most frequently used.
**Sound and broken plurals**

- **sound**: add a suffix: sptar – sptar-ijiet ’hospital’
- **broken**: change the prosody: ktieb – kotba ’book’
### Sound plurals

<table>
<thead>
<tr>
<th>Singular</th>
<th>Plural</th>
<th>Suffix</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>arlogġ</td>
<td>arlogojgi</td>
<td>-i</td>
<td>watch, clock</td>
</tr>
<tr>
<td>omm</td>
<td>ommiji:t</td>
<td>-iji:t</td>
<td>mother</td>
</tr>
<tr>
<td>haddi:m</td>
<td>haddi:ma</td>
<td>-a</td>
<td>worker</td>
</tr>
<tr>
<td>bni:dem</td>
<td>bnedmi:n</td>
<td>-i:n</td>
<td>lazy</td>
</tr>
<tr>
<td>film</td>
<td>films</td>
<td>-s</td>
<td>movie</td>
</tr>
<tr>
<td>saltna</td>
<td>saltni:t</td>
<td>-a:t, -i:t</td>
<td>kingdom</td>
</tr>
</tbody>
</table>

Mayer, Spagnol & Schönhuber (2013)
## Broken plurals

<table>
<thead>
<tr>
<th>Type</th>
<th>Singular</th>
<th>Plural</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>bandiːra</td>
<td>bnaːdar</td>
<td>flag</td>
</tr>
<tr>
<td>B</td>
<td>balla</td>
<td>balal</td>
<td>bundle</td>
</tr>
<tr>
<td>C</td>
<td>borg̩</td>
<td>braːg̩</td>
<td>heap</td>
</tr>
<tr>
<td>D</td>
<td>xmara</td>
<td>xmajjar</td>
<td>river</td>
</tr>
<tr>
<td>E</td>
<td>xatba</td>
<td>xtaːbi</td>
<td>gate</td>
</tr>
<tr>
<td>F</td>
<td>baħar</td>
<td>ibħra</td>
<td>sea</td>
</tr>
<tr>
<td>G</td>
<td>ġdid</td>
<td>ġdodda</td>
<td>new</td>
</tr>
<tr>
<td>H</td>
<td>għarbi [arbi]</td>
<td>għarab [arap]</td>
<td>Arab</td>
</tr>
<tr>
<td>I</td>
<td>wiċċ</td>
<td>uċuħ</td>
<td>face</td>
</tr>
<tr>
<td>J</td>
<td>għaref [aref] [aref]</td>
<td>għoriːf [oriːf]</td>
<td>wise man</td>
</tr>
<tr>
<td>K</td>
<td>għama [ama]</td>
<td>għomja [omja]</td>
<td>blind person</td>
</tr>
</tbody>
</table>

Schembri (2012)
Several sound plurals for one singular

<table>
<thead>
<tr>
<th>Singular</th>
<th>Plural</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>werqa</td>
<td>werq-at</td>
<td>leaf</td>
</tr>
<tr>
<td>werqa</td>
<td>werq-i:t</td>
<td>leaf</td>
</tr>
</tbody>
</table>
Both sound and broken forms
for one singular

<table>
<thead>
<tr>
<th>Singular</th>
<th>Broken plural</th>
<th>Sound plural</th>
<th>gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>bandiːra</td>
<td>bnaːdar</td>
<td>bandiːri</td>
<td>flag</td>
</tr>
<tr>
<td>tapit</td>
<td>twapet</td>
<td>tapiti</td>
<td>carpet</td>
</tr>
<tr>
<td>ūaxix</td>
<td>ūxejjex</td>
<td>ūaxiːti</td>
<td>vegetables</td>
</tr>
</tbody>
</table>
Some forms seem to have both a suffix and a changed prosody:

<table>
<thead>
<tr>
<th>Singular</th>
<th>Plural</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>bni:dem</td>
<td>bnedm-i:n</td>
<td>lazy</td>
</tr>
<tr>
<td>giddi:b</td>
<td>giddib-in</td>
<td>liar (bround)</td>
</tr>
</tbody>
</table>

Borg & Azzopardi-Alexander (1997)
There is a great deal of variation. It is difficult to pinpoint the rules for sound plurals (Borg & Azzopardi-Alexander, 1997), and broken plurals drive scholars of Maltese to despair: "Dwar il-plural miksur m’hemmx regoli". (There are no rules governing the broken plural. (L-Għaqda Tal-Kittieba Maltin. Cited in: Schembri, 2012)
Maltese

- If it is indeed the case that there are no rules governing the broken plural, this means that there is no – linguistic or statistical – structure in the data that allows native speakers to generalize.
- Broken plurals should not be productive.
Maltese

No unmarked shapes

The first syllable of many broken plurals have this shape:

CCVV

(for example: bnaːdar, braːġ.) This is not, as far as we know, an unmarked prosodic shape.
Maltese

Extant accounts

- prosodic morphology
  - Plural forms are not prosodically optimizing, nor are they prosodically unmarked.

- CV-skeleton mapping
  - What skeletons are chosen when?
Maltese

Extant accounts

- prosodic morphology
  - Plural forms are not prosodically optimizing, nor are they prosodically unmarked.

- CV-skeleton mapping
  - What skeletons are chosen when?

- The general idea behind these theories: the phonotactics of the singular determines the shape of the plural. This is a good idea.
Maltese

Hypothesis

- The phonotactics of the singular determines the shape of the plural.
- More frequent items are more likely to be generalized than infrequent items.
To test these hypotheses we created a corpus and we did a production experiment.
We created a corpus of 2369 Maltese nouns

- Taken from the online corpus MLRS Corpus Malti.
- The corpus was checked by means of the online dictionary ġabra.
Plurals in our corpus

Distribution of Plural Types

![Graph showing the distribution of plural types. The graph compares the proportions of sound and broken plurals. It indicates that a higher proportion of plurals are sound compared to broken.]
Maltese experiment

- We created nonce forms based on the forms found in our 2369 word corpus
  - We changed C or V or both systematically:
    - sema ’sky’ → fera, soma, fora.
- We divided the words in frequent (> 50 per million) and infrequent (< 50 per million).
- We chose 90 nonces (30 C-changed words, 30 V-changed words and 30 CV-words.)
- and 22 existing nouns:
  - 5 frequent sound plural words, 5 infrequent ones
  - 5 frequent broken plurals, 5 infrequent ones
  - 2 training items (1 sound, 1 broken.)
Experiment

- Production test with visual presentation
- Software SpeechRecorder
- 38 native speakers of Maltese tested in Malta.
- First one item: *Dik l-stampa ta’ X. This is a picture of X*
- Then 3 items: *ĥafna X? Many X*
## Results

### Qualitative

There is lots a variation in the data:

<table>
<thead>
<tr>
<th>Nonce</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>xgi:gel</td>
<td>xogoliji:t</td>
<td>xogli:t</td>
<td>xogoli</td>
</tr>
<tr>
<td>tolluq</td>
<td>tli:laq</td>
<td>tolluqiji:t</td>
<td>tli:qi</td>
<td>tolluqi</td>
</tr>
<tr>
<td>żepelp</td>
<td>żepelpiji:t</td>
<td>żpi:pel</td>
<td>żepelpi</td>
<td></td>
</tr>
<tr>
<td>follu</td>
<td>folol</td>
<td>folli</td>
<td>folliji:t</td>
<td>folli:t</td>
</tr>
</tbody>
</table>
Results

Sound and broken plurals in nonces and corpus

Distribution of Plural Types: Wugs C

Distribution of Plural Types: Wugs V

Distribution of Plural Types: Wugs CV

Distribution of Plural Types: Wugs CV
Results

Sound plural suffixes

Answers by Sound Plural Suffix

Sound Plural Suffix

- i
- ijet
- iet
- a
- at
- in
- ien
- s
- ejn
- an
- n
- jin

Number

0  500  1000  1500
Results

Broken plural forms

Answers by Broken Plural Type

Proportions

Broken Plural Types

Types: C, B, A, E, No Type, F, D, G, J, H, I

Proportions: ccVVC, (c)CVcVC, CCVCVC
## Results

### Errors in infrequent forms

<table>
<thead>
<tr>
<th>Errors frequent</th>
<th>Errors infrequent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sound</strong></td>
<td><strong>Broken</strong></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><strong>Sound</strong></td>
<td><strong>Broken</strong></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>
Models

Long Short-Term Memory (with the help of Samih Younes)

- Recurrent neural network which we trained to classify Maltese plurals.
  - If there really is no structure at all in the data this should fail.
Models

Long Short-Term Memory (with the help of Samih Younes)
Models

Long Short-Term Memory

- data: 2337 word forms (this is based on a version not checked by ġabra. It contains a few non-nouns.)
- Training: 1869 (broken and sound)
- Validation: 468 (186 broken, 282 sound)
Models

Long Short-Term Memory: Learning

![Graph showing the comparison between Train Loss and Validation Loss over epochs.](image-url)
Models
Long Short-Term Memory: Learning

<table>
<thead>
<tr>
<th>Label</th>
<th>precision</th>
<th>recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>broken</td>
<td>0.94</td>
<td>0.91</td>
</tr>
<tr>
<td>sound</td>
<td>0.94</td>
<td>0.96</td>
</tr>
</tbody>
</table>
## Models

**Long Short-Term Memory and experiment**

<table>
<thead>
<tr>
<th></th>
<th>broken</th>
<th>sound</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSTM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>broken</td>
<td>170 (0.36)</td>
<td>16 (0.03)</td>
</tr>
<tr>
<td>sound</td>
<td>10 (0.02)</td>
<td>272 (0.58)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>broken</th>
<th>sound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>broken</td>
<td>360 (0.5)</td>
<td>60 (0.08)</td>
</tr>
<tr>
<td>sound</td>
<td>0 (0.006)</td>
<td>300 (0.41)</td>
</tr>
</tbody>
</table>
Long Short-Term Memory and experiment

- There is structure in the data
- The classification is pretty good, broken plurals are underestimated and sound plurals overestimated.
Minimal Generalization Learner
Albright & Hayes (2003)

- Model that learns by comparing two inflected forms
- The difference between the forms is formulated as rule.
- The differences are generalized over.
  - \([\text{d\text{\textipa{og}}}, \text{d\text{\textipa{ogz}}}] : \emptyset \rightarrow [z]/[\text{d\text{\textipa{og}}}]+_{[plural]}\).
  - \([\text{b\text{\textipa{æg}}}, \text{b\text{\textipa{ægz}}}] : \emptyset \rightarrow [z]/[\text{b\text{\textipa{æg}}}][_{[plural]}]\).
  - generalized: \(\emptyset \rightarrow [z]/X[+{\text{voice}},-{\text{cont}}][_{[plural]}]\).
Minimal Generalization Learner

- 2225 corpus pairs as input.
- Tested with 20 new words.
Minimal Generalization Learner

<table>
<thead>
<tr>
<th>MGL</th>
<th>broken</th>
<th>sound</th>
</tr>
</thead>
<tbody>
<tr>
<td>broken</td>
<td>3 (0.15)</td>
<td>7 (0.035)</td>
</tr>
<tr>
<td>sound</td>
<td>0 (0.0)</td>
<td>10 (0.5)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Experiment</th>
<th>broken</th>
<th>sound</th>
</tr>
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<tbody>
<tr>
<td>broken</td>
<td>360 (0.5)</td>
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</tr>
<tr>
<td>sound</td>
<td>0 (0.006)</td>
<td>300 (0.41)</td>
</tr>
</tbody>
</table>
Minimal Generalization Learner

• MGL is essentially a linear model.
• Nevertheless is does well.
• again broken plurals are underestimated and sound plurals a bit overestimated.
Naive Discriminative Learner
Baayen, Milin, Djurdjević, Hendrix & Marelli (2011)

- Learns associations between cues and outcomes.
- The cues are singular forms in bigrams.
- The outcomes are plural types (sound, broken, bround).
- These associations are weighted.
- We trained the NDL on our corpus.
- We analyzed our nonce words in bigrams and calculated how the NDL learner would classify them.
- The NDL classified 63% the way our participants did.
  - Excluding frequency from the data, the correct classification dropped to 57%.
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, 2016):
  - 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 Learner

Baayen et al. (2011)

- Learns associations between *cues* and *outcomes*
- The cues are singular forms
  - Bigrams, trigrams, CV skeleton, segments
- Outcomes are plural types (sound, broken, bround)
  - Cue and Outcomes for ktieb ~ kotba:
    - **cue** bigram: #k-kt-ti-ib-b#
    - **outcome** #k → broken, kt → broken, ti → broken, ib → broken, b# → broken
- The associations between cue and outcome are weighted
- Trained the NDL on our corpus
- Used NDL to predict the classification of our nonces
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#
  - Outcomes: 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*
Naive Discriminative Learner

Classification of words in corpus

- Trained on 90% of the corpus and tested with the rest
  - bigrams correctly classifies 73.6% of unseen singulars
  - trigrams correctly classifies 94.6% of unseen singulars
  - CV correctly classifies 63.3% of unseen singulars
Naive Discriminative Learner

Classification of wugs

- How well does the NDL model agree with the classification of wugs by our participants?
- We took the weight of the cues calculated on the basis of the trigram analysis of the corpus
- We pasted the cues together to find the cumulative weight for each wug to find the strongest association for each wug
- We compared the classification of participants with NDL

Table: Classification of wugs by NDL

<table>
<thead>
<tr>
<th></th>
<th>broken</th>
<th>bround</th>
<th>sound</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>broken</td>
<td>0.59</td>
<td>0.009</td>
<td>0.39</td>
<td>good</td>
</tr>
<tr>
<td>bround</td>
<td>0.61</td>
<td>0.03</td>
<td>0.35</td>
<td>bad</td>
</tr>
<tr>
<td>sound</td>
<td>0.33</td>
<td>0.01</td>
<td>0.64</td>
<td>good</td>
</tr>
</tbody>
</table>
Naive Discriminative Learner

- NDL does well.
- Model overestimates sound plurals, and is uncertain about bound plurals.
All models

- The performance of the models seems to correlate with the performance of the native speakers (NDL) and the proportions found in the lexicon.
- Especially NDL suggests that phonotactics play an important role in predicting which singular gets what plural.
- It is still difficult to pin down what it is exactly that speakers use as base for the analogies they produce.
Conclusion

- There is structure in the data.
- Native speakers are able to inflect novel nouns, as sound, broken or bround.
- Several models with very different architectures can learn the plural system relatively successfully.
- NDL learns based on bigrams: dare I say prosodic structure.
- If true, then phonotactics of the singular does indeed determine the plural form.
- There really is no reason to despair.
- (And, as always: much work still needs to be done.)
grazzi ħafna!


