



Knowledge of Maltese singular–plural mappings

Analogy explains it best

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Abstract Which factors determine the choice of a plural allomorph for a new singular form? Are regular mappings stored differently from irregular mappings? Do native speakers only rely on analogical mappings to inflect novel word forms or do they use rules? To answer these questions we used data from Maltese, a language with a split morphology, which has a rich and variable set of concatenative and non-concatenative plural patterns.

We conducted a production experiment, in which we investigated the mapping of a singular onto a plural. We show that this is driven by an interplay between the similarity of novel singular forms with existing singular words and their corresponding plural forms. Moreover, knowledge of the frequency of the plural patterns in the mental lexicon serves as a basis for generalization to novel words. Our results support an analogical model of morphological processing. We do not find evidence that native speakers use default rules.

Keywords Maltese · Morphophonology · Corpus data · Analogy · Default rule · Production experiment

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1 Introduction

A central question of morphology is concerned with the processing and representation of new word forms in the mental lexicon: How are they represented and how is knowledge about them used to inflect novel word forms? The data that answers these questions often involves so-called regular and irregular inflection. For example, the dual-mechanism account (Marcus et al. 1995; Pinker and Prince 1988; Pinker 1998) assumes that regular word forms are generated via categorical morphological rules, which speakers have abstracted from existing word forms in their lexicon. Irregular word forms are not formed by means of rules, but are stored holistically in the mental lexicon. According to this view, rules are used when memory fails to provide an inflected word form (Pinker and Prince 1988). This account can be contrasted with analogy-based theories in which new words forms are generated on the basis of similarity with existing word forms (Albright and Hayes 2003; Daelemans 2002; Skousen 1992; and the papers collected in Blevins and Blevins 2009). Speakers generalize from stored items to new similar word forms by means of analogy, that is new word forms are deduced exclusively by searching the mental lexicon for analogue items and mapping their structure onto the new word forms.

Sonnenstuhl and Huth (2002) provide experimental evidence for a separation of regular and irregular morphology on the basis of the German plural formation. One plural form in German is expressed by *-s*, which is completely regular (e.g. *Auto* – *Autos* ‘car’), another plural is expressed by *-er* (e.g. *Haus* – *Häuser* ‘house’), which is completely irregular, and another one is expressed by *-n*, which is in between these extremes (e.g. *Blume* – *Blumen* ‘flower’) (Sonnenstuhl and Huth 2002). Sonnenstuhl and Huth (2002) focus on the German *-n* plural that is described as a very frequent affix with different degrees of predictability. The plural of most feminine nouns ending in a schwa is expressed by a final *-n*. Nevertheless other singulars also have a plural expressed by a final *-n*, but not as predictably as in the case of feminine schwa-final nouns. Based on the two criteria $+/-$ stem final-schwa and $+/-$ feminine, Sonnenstuhl and Huth (2002) distinguish 4 types of *-n* plurals. In a lexical decision task they compare the frequency effect of these *-n* plurals with regular *-s* and irregular *-er* plurals. The results show word-form frequency effects for all plural types, except for the default regular suffix *-s*. This is taken as evidence for a dual-mechanism account: Irregular plurals are stored as whole word-forms and thus show a word-form frequency effect, while regular *-s* plurals are not stored but generated via categorical morphological rules and thus do not show the frequency effect that is observed with the irregular plurals.

Sonnenstuhl and Huth (2002) separately investigate the lexical representation of *-n* plurals in a cross-modal priming experiment. They find a reduced priming effect for all *-n* plural types except for the highly predictable *-n* plural of feminine schwa-final nouns. Sonnenstuhl and Huth (2002) conclude that this *-n* plural type shows a similar decomposed representation like *-s* plurals. Overall they claim that their findings support a dual-mechanism model of morphological processing.

Similar conclusions about the separation of regular and irregular morphology is provided by Berent et al. (1999) and Berent et al. (2002), who examined the inflection of nouns in Hebrew. In a series of 3 experiments (2 production experiments and a

lexical decision experiment with a rating task) they discover that regular inflection is used as a default rule to inflect novel word forms. If irregular inflection takes place, participants only use it if the presented nonce words show a similarity to existing words. They conclude that nominal inflection in Hebrew is based on a default rule operation.

Kielar et al. (2008), in contrast, provide evidence for a similar processing and representation of regular and irregular morphology on the basis of English past tense forms by means of a cross-modal priming experiment. In their study, they prime present tense targets with morphologically related and unrelated primes, and find similar priming effects for regular as well as for irregular past tense forms. Kielar et al. (2008) take this as evidence for an analogy-based account that does not assume a decomposition of forms but a similar storage for regulars and irregulars.

Further evidence for storage of both regular and irregular word forms is provided by Milin et al. (2009), who investigate the structure of paradigms in Serbian, German and Dutch. They contrast a syntagmatic approach, in which morphologically complex forms are constructed by rule, with a Word and Paradigm approach, in which even complex word forms are stored as wholes (Blevins 2016). On the basis of information-theoretic measures which are used to gauge the entropy of a paradigm, they conclude that word forms in paradigms are stored as wholes. Storage of whole word forms allows language users to predict word forms for cells they have not yet observed (Ackerman and Malouf 2013). Baayen et al. (2018) reach similar conclusions with a computational analysis of Latin verbal paradigms based on whole word forms. They show that, in order to predict word forms for particular entries in the verbal paradigm, it is enough to use complete word forms and a reference to morphemes or stems is not necessary.

The theory of Albright and Hayes (2003) differs from the theories reviewed above. Their Minimal Generalization Learner is a probabilistic stochastic rule model that uses the similarity between the phonological features of English verbs in the mental lexicon and the features of novel verbs to derive a rule to inflect them. For example, the algorithm induces a rule to correctly attach the past tense suffix allomorph [-əd] only to those stems that end in a sound with the phonological features +coronal, +anterior, -nasal and -continuant. Thus, the system is able to correctly attach the suffix after [t] and [d] only (Albright and Hayes 2003).

Their account is a hybrid between analogical and rule-based accounts. Albright and Hayes's (2003) results show that even in the case of regular past tense forms there are groups of verbs that show a similar phonological environment in which a specific morphological change is very likely to occur (see Albright and Hayes's (2003) notion of "islands of reliability"). Native speakers use their knowledge of these groups to generalize to novel word forms with a similar phonological structure.

In short, evidence has been provided for both theories, the dual-mechanism theory and the analogical mechanism theory of morphological processing. Most evidence for these accounts comes from concatenative languages in which a distinction of regular and irregular word forms is assumed to be straightforward. But the distinction between regular and irregular forms is not as straightforward as it may seem at first blush. In a hybrid language that has a large amount of concatenative affixes, and a large amount of non-concatenative forms, it does not make sense to equate regularity

with concatenative morphology and irregularity with non-concatenative morphology (see Hecce 2019, for a discussion of regularity). However, in such a language there is ample room for memory to fail, and hence for a rule to be applied. Maltese, a Semitic language spoken by approximately 400,000 people in Malta (Azzopardi-Alexander and Borg 1997), is such a hybrid language with concatenative and non-concatenative plural patterns (the details of Maltese are explained below). In this study, we will investigate which of the presented accounts can explain the singular–plural mappings for novel words in Maltese. If some forms are processed by means of a rule that operates independently of frequency, we expect an effect similar to the one that has been claimed for the German regular *-s* plural (Sonnenstuhl and Huth 2002). If all word forms are processed by an analogical mechanism, we expect that the frequency of the patterns in the lexicon is the basis for generalizations to novel forms.

1.1 The singular–plural system of Maltese

Historically, Maltese developed from a spoken Maghrebi Arabic variety but due to the colonial history of the island we find extensive influences from Sicilian, Italian and English, which results in a rich morphological variety that is for example visible in its plural system (Ussishkin et al. 2015). Maltese has two different types of singular–plural mappings. On the one hand, it has many plurals that differ from the singular in one suffix. These concatenative plurals are called sound plurals. On other hand, it has plurals that differ from the singular in prosody. These non-concatenative plurals are called broken plurals.

We first introduce sound plurals. The plural of the singular *sptar* ‘hospital’ is expressed by *-ijiet*: *sptarijiet* (Azzopardi-Alexander and Borg 1997). The words that have their plurals expressed in this way are mostly of non-Semitic origin. Depending on the analysis there are between 9 (Azzopardi-Alexander and Borg 1997) and 12 sound suffixes. The differences in analysis depend on which suffixes are grouped together, on the basis of historical or phonological arguments. We identify 12 suffixes, which are illustrated in Table 1.

The column on the left displays the different Maltese sound plural suffixes. The column “Example” shows a singular–plural pair for each of the suffixes. In the case of *-a* final singular nouns the sound plural suffixes substitute the singular feminine marker *-a*. In the case of other singulars, only the plural suffixes are added to the singular stem. Finally, the distribution of sound plural suffixes is illustrated in the right-most column. This distribution is derived from a data set of 2374 Maltese singular–plural pairs taken from the Korpus Malti v.2.0 and 3.0 (Gatt and Čéplö 2013) which we compiled for our study.

We now turn to the broken plurals. These plurals are expressed by a change in prosody, in addition to vowel changes. For example, the word *fardal* ‘apron’ is pluralized as *fra:dal*, in which the coda consonant of the first syllable in the singular ([r]) is in the onset of the first syllable of the plural, and the short vowel in the first syllable of the singular corresponds to a long vowel in the plural (Azzopardi-Alexander and Borg 1997). As a consequence, stress shifts from the final syllable to the penultimate syllable in the plural form as the final syllable is not heavy enough to attract stress anymore (Vella 2009). The words that have their plurals expressed in this way

Table 1 Maltese sound plural suffixes

Sound plural suffix	Example	Gloss	Distribution
-i	<i>karta–karti</i>	‘paper’	612 words
-iet	<i>rixa–rixiet</i>	‘feather’	348 words
-ijiet	<i>omm–ommijiet</i>	‘mother’	326 words
-in	<i>mehlus–mehlusin</i>	‘freed’	78 words
-a	<i>giddieb–giddieba</i>	‘liar’	70 words
-at	<i>triq–triqat</i>	‘street’	39 words
-s	<i>kuxin–kuxins</i>	‘cushion’	21 words
-ien	<i>sid–sidien</i>	‘owner’	5 words
-n	<i>bahri–bahrin</i>	‘sailor’	2 words
-jin	<i>ħati–ħatjin</i>	‘guilty’	1 word
-ejn/ajin	<i>spalla–spallejn</i>	‘shoulder’	1 word
	<i>sieq–saqajn</i>	‘foot’	
-an	<i>qiegh–qieghan</i>	‘bottom’	1 word

Table 2 Patterns of distribution of broken plural forms, based on Schembri (2012)

Plural type	Example	Gloss	CV pattern	Distribution
Type A	<i>fardal–fradal</i>	‘aprons’	CCVVCVC	231 words
Type B	<i>birra–birer</i>	‘beers’	(C)CVCVC	169 words
Type C	<i>bir–bjar</i>	‘wells’	CCVVC	115 words
Type D	<i>ftira–ftajjar</i>	‘type of bread (pl.)’	CC’VjjVC	42 words
Type E	<i>bitha–btieħi</i>	‘yards’	CCVVCV	40 words
Type F	<i>sider–isdra</i>	‘chests’	VCCCV	12 words
Type G	<i>ktieb–kotba</i>	‘books’	CVCCV	11 words
Type H	<i>ghodda–ghodod</i>	‘tools’	(gh)VVCV	4 words
Type I	<i>elf–eluf</i>	‘thousands’	VCVC	3 words
Type J	<i>gharef–ghorrief</i>	‘wise men’	CVCCVVC(V)	2 words
Type K	<i>ghama–ghomja</i>	‘blind persons’	(gh)VCCV	2 words

are mostly of Semitic origin. There are between 11 and 37 different broken plural patterns, depending on the criteria to classify plurals as sound or broken (Schembri 2012). Table 2 displays patterns that are distinguished by Schembri (2012). Broken plural patterns are given in templatic notation or CV templates, which represent the structure of the plural forms as combinations of consonants and vowels.

In her study, Schembri (2012) explores the broken plural in Maltese on the basis of a collection of plural nouns that was compiled by Cardona (1996) for his study. The frequency distribution which is displayed in the rightmost column is based on Schembri (2012).

In addition to the dichotomy between sound and broken plurals, there is a rather substantive amount of words that have both a grammatical sound and broken plural. For example, *kaxxa* ‘box’ has a sound plural, *kaxxi*, and a broken one *kaxex*. More-

over, some noun plurals are formed by combining both plural types, which Mayer et al. (2013) call “the plural of the plural”, a combination of a broken plural pattern and a sound plural suffix: e.g. *tarf–truf–trufijiet* ‘edges’. Some collective nouns like *dubbien* ‘fly’ can take a suffix *-a* to denote one entity of a group of flies and a plural suffix *-iet* for the determinate plural (numbers from two up to ten) (Mayer et al. 2013). Another type of plural formation includes suppletion, e.g. *mara–nisa* ‘women’ (Mayer et al. 2013).

In her recent dissertation, Drake (2018) shows that Maltese native speakers are aware of the split morphological structure of their own language (concatenative vs. non-concatenative patterns) and they use their language specific generalizations even in an “unnatural” artificial language learning task in which speakers were asked to pluralize nonce words after being trained on pluralization strategies for different nonce items. For Maltese plurals, the results show that participants provided plural forms that match the CV templates of existing word forms found in their native language. In addition, native speakers provided the frequent sound plural forms *-i* and *-ijiet* in cases they seemed to be unsure (Drake 2018), a common Maltese pluralization strategy that we have found in this study, too.

This study investigates how Maltese native speakers inflect novel singular nouns. The dual-mechanism theory maintains that regular morphological items are stored and processed differently from irregular ones, whereas the analogical mechanism theory maintains that both regular and irregular morphological items are stored and processed in the same way. We conducted a corpus study in which we established the frequency of patterns in the lexicon and a production test—a wug test (Berko-Gleason 1958)—in which we asked native speakers to inflect both existing and novel words. The predictions of the dual-mechanism theory and the analogical mechanism theory for singular–plural mappings in Maltese are as follows:

Hypotheses

- *Dual-Mechanism Theory*:
 - If Maltese native speakers make use of a morphological rule, we expect that some suffixes or broken plurals patterns are used more frequently for inflecting nonce words independently of the frequency of these patterns in the lexicon.
- *Analogical Mechanism Theory*:
 - If Maltese native speakers build the plural of nonce words on the basis of their similarity to existing words and their plurals, we expect that the proportions of plural patterns in the lexicon will correlate positively with the proportions of plural patterns in the inflection of nonce words.

2 The frequency distribution of sound and broken plural patterns in the Maltese lexicon

In order to study the frequency distributions of plurals in Maltese, we collected a list of Maltese singular and plural forms as they are used by native speakers. We manually compiled a dataset of 2374 Maltese singular–plural pairs from two different sources.

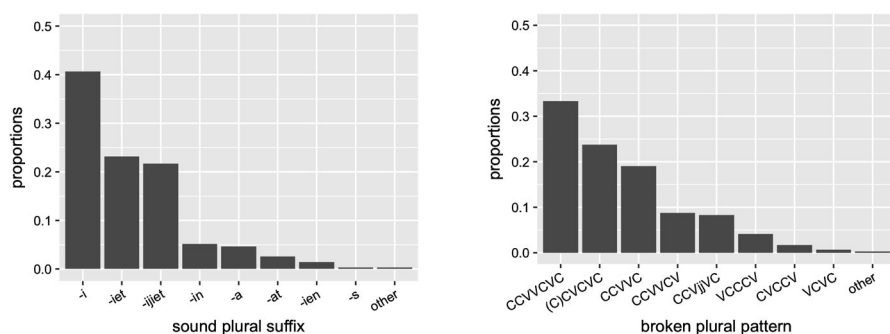


Fig. 1 Distribution of sound plural suffixes and broken plural patterns in the noun list

One part of the dataset was taken from the Korpus Malti v.2.0 and 3.0 (Gatt and Čéplö 2013), a corpus which contains over 130 million word tokens from different text types and genres, and, if necessary, matched with corresponding singular or plural forms from the Maltese online dictionary Ġabra (Camilleri 2013). Another part was taken from a set compiled by Schembri (2012). For each type we established the corpus frequency with the Korpus Malti v.2.0 and 3.0 (Gatt and Čéplö 2013).¹ In addition we coded each word for its CV structure.

Nouns with suppletive plural forms (*mara–nisa* ‘women’) or unclear plural forms, e.g. nouns whose plurality is expressed by both a prosodic change in the plural as well as by a suffix (*tarf–truf–trufijiet* ‘edges’), were not taken into consideration for our distributional analysis (in total: 127 nouns), since we cannot uniquely assign them to the category ‘broken’ or ‘sound plural’. The final data set contained 748 broken plural nouns and 1499 sound plural nouns (in total: 2247 nouns).

Figure 1 shows the distribution of the different sound plural suffixes (left panel) and broken plural patterns (right panel) in the final data set that we used for the present study. We estimated the proportions for each of the different sound plural suffixes and broken plural patterns that are displayed on the x-axes of the figures. Sound plurals represent the majority of plural forms in our list (67%). As the left panel of the figure illustrates we can identify three main sound plural suffixes: the Romance suffix *-i* and the Semitic suffixes *-ijiet* as well as *-iet*. In total our noun list contained 12 different sound plural suffixes (please note that possible variants of a suffix are counted as individual suffixes here). Suffixes that occurred only once are subsumed under the category ‘other’ (in total: 5 suffixes). Broken plural forms make up a proportion of about 33% in our data set. This is in line with other counts for Semitic languages, see for example Dawdy-Hesterberg and Pierrehumbert (2014) for a distribution of Arabic plural types. In total our data set contained 10 different broken plural patterns. Again, we find three main patterns, as shown in the right panel of Fig. 1. The category ‘other’ contains two infrequent broken plural patterns.

¹The manual compilation of the data set as well as the nature of the Korpus Malti may have impacted the frequency distribution in our data set. We made every effort to include as many tokens as possible for all relevant plural types in our data set.

3 Production experiment

We conducted a production experiment in which we elicited the production of plural forms for existing Maltese singular nouns and phonotactically legal nonce singular nouns.

3.1 Participants

Eighty adult native speakers of Maltese (50 women, 30 men) with a mean age of 24.6 years took part in the experiment. They were recruited by means of an online sign-up sheet and announcements at the University of Malta. They received €4 upon completion of the task and participated voluntarily. None of them reported hearing or visual impairments that have not been corrected to normal vision.

3.2 Items

The production experiment consisted of existing Maltese singular nouns and nonce singular forms. All singular forms were embedded into the carrier sentence *Dik l-istampa ta?* ‘that is the picture of’ and were supported by pictures of exactly one item or animal.

Participants were required to complete phrases starting with the word *Ħafna* ‘many’ accompanied by a picture of three items or animals of the same kind to trigger plural forms.

Figure 2 shows an example trial of our experiment. Pictures of familiar entities were taken from the Snodgrass and Vanderwart (1980) collection, whereas pictures of fantasy animals were partly taken from van de Vijver and Baer-Henney (2014) and partly prepared for our study.

We used twenty-two existing singular nouns from our dataset of Maltese as experimental stimuli. They consisted of eleven singulars with a broken plural form and eleven singulars with a sound plural form. Two of these existing nouns (*kelb* ‘dog’ with a broken plural form and *kappella* ‘chapel’ with a sound plural form) were used as items for the training trial. The ten remaining sound plural words and the ten remaining broken plural words used in the experimental phase of the production experiment. We also controlled for the corpus frequency of the words by arbitrarily setting the following threshold: A frequency below 50 instances per million words was classified as infrequent and above 50 instances per million words as frequent. Five of the words in the experiment were frequent and five were infrequent nouns. Frequent items had an average frequency of 255 per million words (63–854 instances per million words) while infrequent items had an average frequency of 9 per million words (0–36 instances per million words).

We constructed nonce words from words in our dataset by changing either (i) the consonants or (ii) the vowels or (iii) both systematically. Consonants were changed according to the following rules: a fricative was interchanged with a fricative, a stop was interchanged with a stop, an approximant was interchanged with an approximant, an affricate was interchanged with an affricate. The nasals /n/ and /m/ were interchanged with a liquid to avoid similarities to the existing nouns. Following this

Fig. 2 Example of a trial of our experiment



Table 3 Nonce words: changes of consonants

Manner of articulation	Changes
fricatives	f↔s, v↔z, h↔ʃ
stops	b→d→g, p↔t, k↔ʔ
affricates	ts→tʃ→tʃ
approximants	j↔w
nasals & liquids	n↔l, m↔r

procedure we ensured that the phonotactics of the existing items is maintained and thus, that the resulting nonce items are similar to existing Maltese nouns to different degrees. It is important to ensure the phonotactic viability of the nonce words as it has been shown that even 19-months old children do not treat phonotactically illegal nonce words as potential lexical candidates, while they treat phonotactically legal nonce words as potential lexical candidates (Friedrich and Friederici 2005). See Table 3 for an overview. In cases where a noun contained a derivational suffix like *-zzjoni* or the feminine marker *-a* these suffixes and markers were not changed.

Vowels were changed according to the following rules: i↔u, e↔o and a→e (except for *-a* at the end of a word). The procedure leads to three lists of nonce words: (i) one set of nonce words with changed *consonants* (list C), one set of nonce words with changed *vowels* (list V) and (iii) one set of nonce words with changes in both

consonants and *vowels* (list CV). We used 47 words with a Semitic origin, and 37 with a non-Semitic origin.

Despite careful checking, a few items appeared as duplicates in the experiment. We deleted the duplicated occurrences and did not use them in our analysis. We ended up with 28 nonce words from each of the three lists. In list C, 9 nouns had an existing word with a broken plural form as a base, 9 nouns had an existing word with a sound plural form as a base and 10 nouns had an existing word with both plural forms as a base. In list V, 9 nouns had an existing word with a broken plural form as a base, 10 nouns had an existing word with a sound plural form as a base and 9 nouns had an existing word with both plural forms as a base. Finally in list C, 10 nouns had an existing word with a broken plural form as a base, 8 nouns had an existing word with a sound plural form as a base and 10 nouns had an existing word with both plural forms as a base (in total: 28 broken plurals, 27 sound plurals, 29 both plural forms). The final list of nonce items was checked by a native speaker to ensure that the procedure of creating nonce words had not led to an existing word.

3.3 Procedure

We ran the production experiment with the software SpeechRecorder (Draxler and Jänsch 2004) on a Windows computer in a sound-attenuated booth of the Cognitive Science laboratory at the University of Malta. All words were presented visually with additional pictures of familiar and fantasy animals or items. In total, the experiment lasted approximately 30 minutes. All answers were recorded and manually annotated with Praat (Boersma and Weenink 2013).

Prior to the experiment, the person running the experiment briefly introduced the procedure. The participants were told that they were allowed to ask questions and interrupt, or stop participating in the experiment at any time. After the introduction there was a short training phase to familiarize the participants with the experiment and to define the settings for the recordings.

During the training phase two existing singular forms having a sound and a broken plural form, *kelb* ‘dog’ and *kappella* ‘chapel’, were presented. The training phase started when the participants reported that they were ready to start. Subsequently, speakers had to read a short story in Maltese to be prepared for the following images of fantasy animals. The short story informed them about the adventures of a pirate who discovered an uncharted island with new animal species. Again, the test phase started when the speakers reported that they were ready to start with the experiment.

Each recording of the test phase consisted of three phases, shown by a traffic light symbol that is part of the software SpeechRecorder and that was always visible to speaker and researcher (see also Draxler and Jänsch 2004). During the yellow phases, the speakers prepared their utterance. When the light turned green, they were asked to give an answer to the displayed sentence. The recording time was set to 4000 milliseconds, with a pre-recording delay of 1500 ms and a post-recording delay of 500 ms to capture as many answers as possible and avoid signal truncation. The items were presented in random order. The researcher clicked once to proceed to the next item and to immediately start a recording. Recordings could be repeated whenever the participants were not ready within the set recording time.

Table 4 Proportion of errors in plurals for existing singular nouns

	Frequent	Infrequent
Sound	5/400 (1.3%)	14/400 (3.5%)
Broken	1/400 (0.3%)	177/400 (44.3%)

4 Results

To investigate what knowledge Maltese native speakers use as a basis to classify singulars as having a particular plural suffix or plural pattern we had asked the participants of our production experiment to provide plural forms for existing Maltese nouns and phonotactically legal nonce words. In total, we recorded 8973 responses. We excluded recordings from the following analyses that had a bad sound quality and could not be analyzed with Praat (Boersma and Weenink 2013). We first provide a descriptive analysis of our results and then provide a logistic linear mixed effects model analysis.

4.1 Error analysis for existing singulars

For existing Maltese singular nouns we expect that there will be fewer correct plural forms for infrequent nouns than for frequent nouns. A plural form that was given in the dictionaries (Aquilina 1987; Camilleri 2013) was considered correct. If the participants built non-canonical plural forms, that is forms we did not find in the dictionaries, or simply repeated the given singular form, their responses were counted as incorrect.

The results are illustrated in Table 4. As the low percentage of incorrect answers in the left column indicates, participants performed very well on frequent forms, independent of the type of plural. There were very few incorrect responses for frequent sound plural forms, e.g. *ffura* (sg.)–*ffur* (incorrect pl.) instead of *ffuri* (correct pl.). Statistical analysis revealed that the difference between incorrect answers for frequent and for infrequent words compared to the plural type is statistically significant ($p < 0.05$, Fisher’s exact test).

As was expected, participants are more uncertain about infrequent nouns. The right column of the Table 4 indicates the proportion of incorrect responses for infrequent items. Especially with infrequent nouns that have a broken plural form we find the highest amount of incorrect answers. A quick look into the errors showed that many involved adding the plural suffixes *-i* (74/177), *-ijiet* (27/177) or *-iet* (30/177), but there were also a substantial amount of different broken plural patterns (23/177 type C; 8/177 type A; 5/177 type D; 2/177 type B and 2/177 type E) and 5 repetitions of the singular words. These errors imply that broken plural forms are available to native speakers for generalization, despite their lower overall type frequency in comparison to sound plural forms.

With respect to our hypotheses, these results do not provide an answer yet. The participants could have relied on a rule, which they apply to words they do not know well, or they form plurals for singulars they do not know well on the basis of their similarity to words in their lexicon. In order to fully understand the knowledge of the Maltese singular–plural mapping native speakers use to inflect novel word forms, we need to have a look at the results for the nonce items.

Table 5 Excluded plural forms

Reason for exclusion	Example
No answer	–
Repeated singular	<i>gett–gett</i>
Unattested plural	<i>hebž–hebiež</i>
Plural of the plural	<i>nalza–nlazi</i>
Additional sequences/changed material	<i>tupa–tupletini</i>

Table 6 Plural forms of nonce singulars provided by participants

Nonce Singular	Speaker A	Speaker B	Speaker C	Speaker D
<i>xogol</i>	<i>xgiegel</i>	<i>xogolijiet</i>	<i>xogliet</i>	<i>xogoli</i>
<i>tolluq</i>	<i>tlielaq</i>	<i>tolluqijiet</i>	<i>tlieqi</i>	<i>tolluqi</i>
<i>follu</i>	<i>folol</i>	<i>folli</i>	<i>follijiet</i>	<i>folliet</i>
<i>žepelp</i>	<i>žepelpijiet</i>	<i>žepelpi</i>	<i>žiepel</i>	<i>žepelpi</i>

4.2 Frequency analysis of answers to nonce words and distribution of plural patterns in the lexicon

For phonotactically legal nonce singular words we expect that the similarity of the singular nonce forms to existing words and their associated plural determines the shape of the nonce plural forms. If there are patterns in the nonce forms that are used more often than we can expect on the basis of the lexical frequency of these patterns, this is evidence for the use of a frequency-independent default rule and thus supports a dual-mechanism model of morphological processing. The great amount of different sound and broken patterns would make it possible that the memory of speakers fails for both sound and broken plurals.

We excluded responses in which the participants did not provide an answer, repeated the singular word, used unattested plural forms, built “plural of the plural” forms (Mayer et al. 2013) or changed the singular word by inserting additional sequences or changing material (in total: 659 forms out of a total of 8973 answers). Examples for these cases are given in Table 5.

A plural form like *hebiež* in the third row of Table 5 was considered as unattested plural form since we do not find a corresponding type for the CV template in Schembri’s (2012) work (see also Table 2). A plural form like *nlazi* in the fourth row of Table 5 was counted as a combination of a broken and a sound plural form (“plural of the plural”) and thus excluded from the analysis. Finally, the last row of Table 5 shows an example of an answer where the participant decided to include an additional sequence *-letin-* to the singular form to create an entirely new plural word *tupletini*. Such instances were excluded from the analysis.

Overall, though, the participants provided a great number of different plural forms per nonce item. We provide a few illustrative cases of this variation in Table 6.

The column ‘Nonce Singular’ on the left contains four of the 90 nonce singular forms that were presented in the experiment. The ‘Speaker’ columns contain a sample of the answers of our participants, indicating the variation in their plural responses.

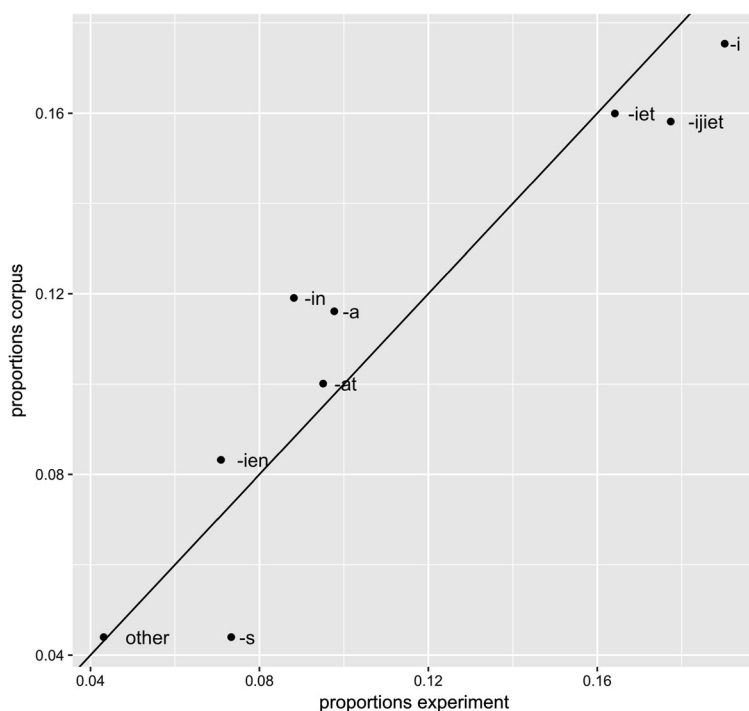


Fig. 3 Proportion of different sound plural suffixes in corpus and experiment and their correlation

Let us first turn to the variation of different sound plural forms given by participants. Figure 3 gives an overview of the sound plural suffixes the speakers have used with the nonce items compared to the suffixes we found in our noun list. Especially the suffixes *-i*, *-ijiet* and *-iet* turned out to be used very frequently throughout the whole experiment, as illustrated in Fig. 3. According to Azzopardi-Alexander and Borg (1997) all three suffixes occur frequently with Romance loan words. Whereas *-iet* and *-ijiet* figure in Semitic nouns, too, the suffix *-i* has a Romance origin and is used with Romance loan words only. In 2703 of 5404 (50%) cases participants added the Romance plural suffix *-i* to the nonce singular stems. For 1589 of 5404 (29%) words we find the suffix *-ijiet* and for 917 of 5404 words (17%) the suffix *-iet* was provided.

As these three suffixes are the most frequent ones in our dataset, too, their proportions in the plurals of nonce words mirror the distribution of sound plurals in the Maltese lexicon. Participants used the most common plural suffixes of their language to generalize to new forms. This is in line with the results of Drake (2018).

In a regression analysis of the log-transformed frequency of suffixes in our dataset and the log-transformed frequency of the suffixes in our experiment, we found that correlation between them was 86% (multiple R -squared = 0.86, adjusted R -square = 0.84, $F(45.72, 1)$, $df = 7$, $p = 0.0002$). The log-transformed frequency of the suffixes in our experiment was used as the dependent variable, the log-transformed

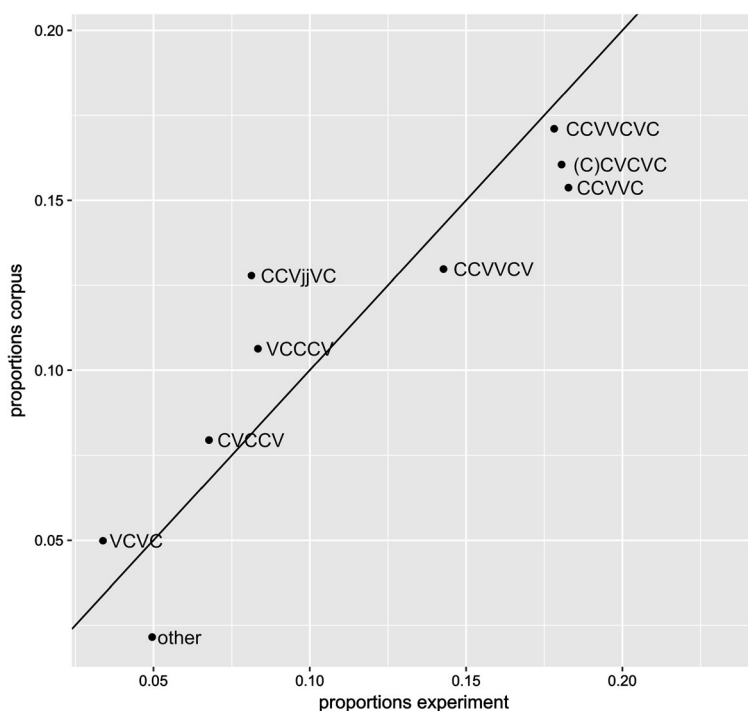


Fig. 4 Proportion of different broken plural patterns in corpus and experiment and their correlation

frequency of suffixes in our dataset was used as the independent variable of the model to calculate the correlation. This correlation is illustrated in Fig. 3.

Let us now turn to the different broken plural patterns participants used with nonce stems in the experiment. Our classification of broken plural types relies on the distinction that can be found in Schembri's (2012) study, in which she distinguishes eleven broken plural types based on the different CV structures of the plural forms, see Table 2 for an overview.

In total, our participants produced 1262 broken plural forms in the production experiment. 60 nouns could not be assigned to one of Schembri's (2012) broken plural types. For the remaining 1202 forms, the three most frequent patterns we find are CCVVC (377 of 1202 words, 31%) (C)CVCVC (351 of 1202 words, 29%) and CCVVCVC (325 of 1202 words, 27%), consequently following Schembri's (2012) types C, B and A. Figure 4 depicts the proportion of the different broken plural patterns our participants used with nonce words in the experiment compared to the proportion of these patterns in our corpus.

In a regression analysis of the log-transformed frequency of patterns in our dataset and the log-transformed frequency of the patterns in our experiment, we found that the correlation between them was 82% (multiple R -squared = 0.82, adjusted R -square = 0.79, $F(31.06, 1)$, $df = 7$, $p = 0.0008$). Again, the log-transformed frequency of the patterns in our experiment was used as the dependent variable, the log-transformed frequency of patterns in our dataset was used as the independent

variable of the model to calculate the correlation. This correlation is illustrated in Fig. 4.

In summary, the proportion of the three most frequent patterns within all broken plural responses for nonce words is 87%. The patterns A, B and C make up the majority of the patterns in our experimental data. Participants rarely used one of the other possible more infrequent types available in Maltese. This is in line with Schembri's (2012) categorization of broken plural forms and her three most frequent patterns and also with the proportion of these patterns we find in our corpus, hence again participants used the most common broken plural patterns of their language to generalize to new forms they had never heard before.

4.3 Regression analysis of the answers of the participants

To analyze the effects on the choice of the plural form for nonce words, we fitted a generalized linear mixed-effects model using the `lme4` package (Bates et al. 2015) in the R environment (R Core Team 2019). In our model `ANSWEROFPARTICIPANTS` was used as binary dependent variable (`sound`, coded as 1, or `broken`, coded as 0), the variables of interest `CHANGE` and `BASE` were used as predictors.

As we formed nonce words by changing consonants and vowels or both of existing Maltese words, the variable `CHANGE` consists of the three levels 1. `consonants`, 2. `vowels` and 3. `consonantsvowels` to account for possible effects of changing segments in the words to create the nonce words. `CHANGE` was then entered in the model as two linearly independent contrasts using Helmert coding to avoid convergence problems.

The first contrast C1 compared the list `consonantsvowels` to the lists `vowels` and `consonants` (`consonantsvowels` = 0.5, `vowels` and `consonants` = -0.25). The second contrast C2 compared the lists `vowels` and `consonants` with each other (`consonantsvowels` = 0, `vowels` = -0.5, `consonants` = 0.5).

The variable `BASE` was coded as `broken`, `sound` or `both`, referring to the plural type of the noun that formed the basis of the nonce words. Again, this three-level variable `BASE` was then entered in the model as two linearly independent contrasts. The first contrast C1 compared the plural `both` to the plurals `sound` and `broken` (`both` = 0.5, `sound` and `broken` = -0.25). The second contrast C2 compared the plurals `sound` and `broken` with each other (`both` = 0, `sound` = -0.5, `broken` = 0.5).

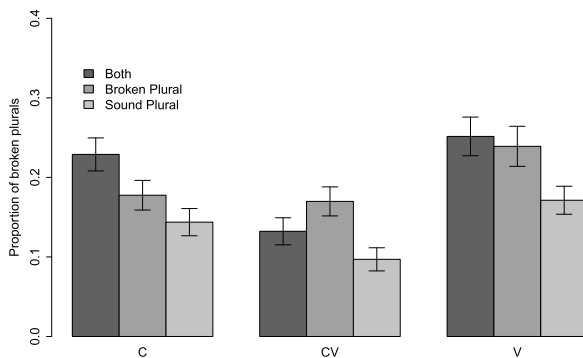
Both variables, `BASE` and `CHANGE`, were included as fixed effect without interaction terms into the model, as an ANOVA ($p < 0.8368$) indicated that there is no significant difference between the complex model with the interaction term and the simple model without an interaction.

The variables `ITEM` and `PARTICIPANT` were included as random effects. Following Barr et al. (2013) all possible random slopes were specified and the maximal random effect structure supported by the data was included.

Two questions remain unanswered yet: Did the change of consonants and vowels influence the choice of plural forms of our participants? Did the plural form of the word that has been used as a base for these changes influence the choice of plurals

Table 7 GLMM model for plural forms of nonce words

	Estimate	Std. error	z-Value	Pr(> z)
(Intercept)	2.1630	0.1808	11.961	<2e-16 ***
CHANGE.C1	0.8455	0.3659	2.311	0.0209 *
CHANGE.C2	0.2558	0.3144	0.814	0.4159
BASE.C1	-0.5878	0.3575	-1.644	0.1001
BASE.C2	-0.7482	0.3200	-2.338	0.0194 *

Fig. 5 Proportion of broken plural responses for each level of Change for nonce words and their Base

of the participants? To test these possibilities a model was fitted according to the procedure described in detail above. The results of the logistic regression model are displayed in Table 7.

We find a significant effect ($p < 0.05$) for our first contrast for the variable Change that compared the list consonantsvowels to the lists vowels and consonants (consonantsvowels = 0.5, vowels and consonants = -0.25). We also find a significant effect for our second contrast for the variable Base that compared the plurals sound and broken with each other (both = 0, sound = -0.5, broken = 0.5). The results indicate that both variables, the change of consonants and vowels to build nonce words and the plural form of the existing word that has been used as a base to create new words, indeed influenced the production of plural forms.

As can be seen in Fig. 5, which shows the proportion of broken plural responses for each type of nonce word, the data revealed a clear effect for the two variables Change and Base. We find the highest proportion of broken responses for nonce words that were built by changing the vowels of existing Maltese singular nouns (rightmost three bars). When both, consonants and vowels, were changed, participants provided fewer broken plural responses (three bars in the middle). In addition, Fig. 5 illustrates that the plural form of the word that was used as a base to create nonce items influenced the proportion of broken plural responses. Participants provided more broken plural responses for words that had both plural forms (dark grey bars) or a broken plural form as a base form (middle grey bars).

4.4 Summary

The experiment has shown that Maltese native speakers are more certain about sound plural forms (see Table 4) and, in general, use these forms more frequently. When presented with new word forms, the suffixes and the patterns of plurals created by native speakers show a positive correlation with suffixes and patterns found in their language (see Figs. 3 and 4).

The middle triplet of bars in Fig. 5 show that changing both consonants and vowels of existing words simultaneously leads to the lowest probability of broken plural responses. The rightmost and the leftmost triplet of bars in Fig. 5 shows that more broken plural answers were given for nonce words created by changing the vowels of existing words and for nonce words created by changing the consonants of existing words. This may be surprising in the light of findings about the difference in the role of informativity between consonants and vowels (Boudelaa 2014; Cutler et al. 2000; Turnbull and Peperkamp 2017). These studies reported that consonants affect lexical processing to a higher degree than vowels. However, we believe that the differences between the results reported in the literature and our results are due to methodological differences. Our experiment focuses on the similarity of nonce words to existing words and less on the informativity of consonants and vowels.

The reason for the higher probability of sound plural answers for nonce items created by changing both vowels and consonants in existing words is that there are more sound plurals in the Maltese lexicon (see Sect. 2), and as a result these nonces have a better chance at resembling a sound singular than a broken singular. However, as can be seen in Fig. 3 this does not lead to an overabundance of certain suffixes in the plural nonce forms. Such an overabundance would have been clear evidence for the use of a default rule by the participants and would have supported a dual-mechanism model for Maltese singular–plural mappings. Rather, the choice of suffixes that are frequent in the lexicon for plurals of nonce words reflect the fact that these suffixes will fit a variety of singular forms.

In addition, the analysis revealed a significant effect for the base of the nonce (see Table 7): if a nonce is based on a sound singular it is likely to be given a sound plural and if a nonce is based on a broken plural it is likely to be given a broken plural. This means that generalizations are made over the lexicon, and that the similarity of a novel form to existing singulars and their plurals is used to predict its plural.

5 Discussion

The aim of this study was to investigate the knowledge of singular–plural mappings of Maltese native speakers. As this knowledge is used by native speakers to create new forms, we asked native speakers to create plurals for nonce singulars, in addition to providing plurals for existing words. Our results show that native speakers are able to generalize to novel nouns and use the most common suffixes and CV patterns for this task.

A review of the relevant literature on morphophonological mappings has provided evidence for two different views on how to best model this knowledge. This led us to formulate two hypotheses, which we repeat from the end of Sect. 1.

– *Dual-Mechanism Theory:*

- If Maltese native speakers make use of a morphological rule, we expect that some suffixes or broken plurals patterns are used more frequently for inflecting nonce words independently of their frequency of these patterns in the lexicon.

– *Analogical Mechanism Theory:*

- If Maltese native speakers build the plural of nonce words on the basis of its similarity to existing words and their plurals, we expect that the proportions of plural patterns in the lexicon will correlate positively with the proportions of plural patterns in inflections of nonce words.

We have shown that the proportions of the different sound plural suffixes and broken plural patterns provided by the participants for the nonce words positively correlated with the proportions of these suffixes and patterns in the data set we created for the purpose of this study (displayed in Fig. 3 and Fig. 4). These results are consistent with the analogical mechanism hypothesis that the knowledge of Maltese native speakers of the singular–plural mappings is generalized to novel words on the basis of the similarity of the novel word to existing singulars and their associated plural form. The knowledge of native speakers concerning morphophonological patterns such as singular–plural mappings is analogical. It is determined by the frequency of the patterns in the lexicon of the native speakers. New words are compared with words that are stored in the mental lexicon, and the inflected forms of the new words depend on the similarity to existing words and their inflection. The more a new word resembles a particular existing word, the more likely it is that the new word will be inflected in the same way (Albright and Hayes 2003; Berko-Gleason 1958; Bybee and McClelland 2005; Ernestus and Baayen 2003; Hayes and Londe 2006; McClelland and Patterson 2002a,b; Rumelhart and McClelland 1986).

We did not find evidence for a default rule in Maltese, such as has been proposed for German, English or Hebrew (Berent et al. 2002; Clahsen et al. 1992; Kim et al. 1991; Marcus et al. 1995). Such a default rule would be applied independently of the frequency of the words that are under investigation, for example in those cases where our nonces were not similar enough to existing items. Since we created nonces with different degrees of similarity to existing words, we are in principle able to distinguish between nonces that are more similar to existing words (those that are created by changing only the vowels or the consonants) and less similar to existing words (those that are created by changing both vowels and consonants of existing words). We would then see a difference between more and less similar nonces. However, even for nonces that were most dissimilar to the existing word we found that the plurals of nonces based on sound singulars differed from plurals based on broken singulars (see Table 7), and the middle triplet of bars in Fig. 5 shows that both sound and broken plurals were given for such nonces. Moreover, the fact that the proportion of suffixes and patterns in our dataset and in our experimental data are both strongly positively correlated shows that our participants did not use a particular suffix or a pattern more often than is warranted on the basis of the frequency of these patterns in their lexicon. A final argument against a default rule comes from the error analysis of the answers to existing nouns (see Table 4). We found most errors for infrequent broken plurals, but the errors reflect the frequency of patterns in the lexicon, and the participants did not only produce sound plurals for such less known broken plurals.

From the point of view of morphological theory our results are in line with the Word and Paradigm approach of the mental lexicon (Baayen et al. 2018; Blevins 2016; Milin et al. 2009). Our results show that speakers of Maltese have stored both sound and broken plurals as whole words. This is shown positively, by the presence of a similarity effect, and negatively, by the absence of evidence of a default rule application.

In this study we have shown that the knowledge of Maltese native speakers concerning novel singular plural mappings is, despite showing a bewildering variety of possible mappings in existing words and a great deal of variation, based on analogy with existing words. Future studies are necessary to delve deeper into the knowledge of native speakers about the complexity of the plural formation in Maltese. We feel justified, however, in saying that the assessment “Dwar il-plural miksuri m’hemmx regoli” (There are no rules governing the broken plural) (Ghaqda Tal-Kittieba Maltin 1998:165) is too pessimistic.

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Appendix A: Experimental items: Nonce words

Nonce-singular	Corpus frequency	Existing noun	Change
ċumlapa	258,68	ġurnata	C
gam	290,65	dar	C
dizza	142,85	biċċa	C
somra	121,71	forma	C
xogol	0,02	hodon	C
baċċa	0,42	gagġa	C
dumgenn	1,19	burdell	C

Nonce-singular	Corpus frequency	Existing noun	Change
nalza	9,27	lanča	C
fullama	1,75	sunvara	C
sapp	882,95	fatt	C
niči	809,02	ligi	C
tampi	600,17	parti	C
lukkaf	276,79	nuqqas	C
mapa	147,76	rata	C
sehir	0,3	fehim	C
swuma	2,18	fjura	C
žabanza	11,16	vaganza	C
pamissa	15,99	tariffa	C
vriel	1056,26	žmien	C
pagğa	54,49	tazza	C
lakma	43,29	naqra	C
xarfa	41,03	hamsa	C
gamda	623	darba	C
zammu	0	čarru	C
čolpa	0,09	gonta	C
guddiela	0,44	dubbiena	C
gadma	0,26	dabra	C
faxpa	2,28	sahta	C
bnudom	253,9	bniedem	V
sona	2238,3	sena	V
tufol	101,81	tifel	V
beher	165,25	bahar	V
lipi	1,54	lupu	V
kentin	0,96	kantun	V
follu	0,38	felli	V
hebol	3,64	habel	V
xufor	7,92	xifer	V
pertut	969	partit	V
porsina	685,63	persuna	V
kent	481,62	kont	V
sottir	319,8	settur	V
gripp	220,34	grupp	V
tolluq	0,05	tellieq	V
vetent	6,05	votant	V
lozzjoni	9,78	lezzjoni	V
tupa	0,99	tipa	V
qeddus	0,06	qaddies	V

Nonce-singular	Corpus frequency	Existing noun	Change
truq	494,38	triq	V
weqt	851,41	waqt	V
dewra	14,27	dawra	V
hebż	22,3	hobż	V
qelba	30,64	qalba	V
zolluqa	0	zellieqa	V
ċeppotta	0,1	ċappetta	V
telleb	0,68	tallab	V
torha	0,26	terha	V
kempu	489,62	qorti	CV
fohor	242,18	sehem	CV
gejn	262,17	dawl	CV
qerma	420,21	kamra	CV
snif	476	flus	CV
xedda	0	habba	CV
nulsa	0,23	linfa	CV
peżna	0,19	tavla	CV
skuma	1,76	fqira	CV
delqa	2,92	banka	CV
tetni	716,67	poplu	CV
ċimlen	107,83	ġurnal	CV
nulwa	137,39	linja	CV
negħda	172,18	logħba	CV
leffed	1,76	nassab	CV
gusopp	9,23	difett	CV
elluren	14,09	annimal	CV
nedimist	10,51	laburist	CV
ghepda	8,11	ghatba	CV
kepna	6,43	qatla	CV
luvna	6,38	nizla	CV
kduna	4,58	qbiela	CV
qonra	161,5	kelma	CV
homka	0,05	xerqa	CV
rilkem	0,1	munqar	CV
ġett	0,79	zopp	CV
fows	1,07	sejf	CV
rulpla	0,25	mintna	CV

Appendix B: Experimental items: Existing words

Singular	Corpus frequency (instances per million words)
dar	290,65
kelma	161,5
ktieb	97,75
ballun	63,25
gurnata	258,68
borka	0,06
troffa	0,07
suffara	3,88
labra	4,14
xini	2,37
karoza	168,91
pajjiz	853,60
mistoqsija	370,13
minuta	142,69
ittra	145,02
trakk	14,93
arma	36,41
annimal	14,09
fjura	2,18
ferita	11,44

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