

Maltese Plurals: Phonotactics, Variation and the Structure of the Mental Lexicon

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Abstract

Maltese, a Semitic language with two morphological systems, shows a bewildering variety of concatenative and non-concatenative plurals (*sound* vs. *broken* plurals). Using psycholinguistic experiments and computational models, this thesis investigates what factors are important for pluralization in Maltese.

In the first study, reported in Nieder, van de Vijver, et al. (2021a), a production experiment was used to investigate the mapping of a singular onto a plural. We show that speakers use their knowledge about existing singulars and about plural pattern frequency to generalize to new words.

In the second study, reported in Nieder, van de Vijver, et al. (2021b), we investigated the storage and processing of Maltese nouns with a cross-modal priming experiment. The results show no difference in reaction times for Maltese plurals, but indicate that pattern frequency and the similarity to existing words are important factors for processing.

In the third study, reported in Nieder, Tomaschek, et al. (2021), a word-based approach is tested for Maltese plurals with three computational models. Using the Tilburg Memory-Based Learner, the Naive Discriminative Learner, and an Encoder-Decoder network, we show that it is possible to classify and produce Maltese nouns without referring to morphemes.

This thesis concludes that assuming a decomposition into morphemes is not necessary for Maltese, instead morphological generalizations are based on words that are stored as wholes in the mental lexicon.

Abstract

Das Maltesische, eine semitische Sprache mit zwei morphologischen Systemen, zeigt eine große Anzahl an konkatenativen und nicht-konkatenativen (*sound* vs. *broken*) Pluralen. Durch psycholinguistische Experimente und computationelle Methoden untersucht diese Dissertation, welche Faktoren für die maltesische Pluralbildung ausschlaggebend sind.

Die erste Studie (Nieder, van de Vijver, et al., 2021a) nutzt ein Produktionsexperiment, um die Bildung eines Plurals auf Basis des Singulars zu testen. Wir zeigen, dass maltesische Sprecher Wissen über existierende Singulare und Pluralfrequenz für die Generalisierung auf neue Wortformen nutzen.

Die zweite Studie (Nieder, van de Vijver, et al., 2021b) untersucht die Verarbeitung maltesischer Nomen mit einem cross-modal priming Experiment. Die Ergebnisse zeigen keine Unterschiede zwischen den Reaktionszeiten der Plurale, beweisen jedoch, dass die Pluralfrequenz und die Ähnlichkeit zu existierenden Wörtern wichtig für die Verarbeitung sind.

Die dritte Studie (Nieder, Tomaschek, et al., 2021) testet ein Wortform-basiertes Modell mit computationellen Methoden. Mit Hilfe des Tilburg Memory-Based Learners, des Naive-Discriminative Learners und eines Encoder-Decoder Netzwerks, zeigen wir, dass eine Klassifikation und Produktion maltesischer Nomen ohne Zugriff auf Morpheme möglich ist.

Die Dissertation kommt zu dem Schluss, dass eine Dekomposition in Morpheme für maltesische Plurale nicht notwendig ist. Wortformen sind stattdessen als Ganzes im mentalen Lexikon gespeichert.

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1. Introduction

The question as to what knowledge native speakers use for building complex word forms and how this knowledge is stored in the mental lexicon has been the main topic of an on-going debate in morphology over years and has led to different theoretical approaches.

Broadly speaking, there are two competing views: The Single-Mechanism account versus the Dual-Mechanism account.

A Single-Mechanism account, on the one hand, assumes that all complex words are stored as wholes and processed in the same way. There is one single mechanism that is responsible for generalizing to new word forms. On a Single-Mechanism account a decomposition into separate morphemes is not necessary anymore, raising the controversial but interesting question if the morpheme still should be the basic unit of morphology as it has been declared decades ago (Baayen et al., 2018; Baayen et al., 2019; Blevins et al., 2016).

On the other hand, a Dual-Mechanism of morphological processing assumes that complex words are stored in different ways based on the regularity of word forms. According to this theory, regular word forms, such as *walk - walked*, are built through a regular rule application, and therefore a decomposition into separate morphemes has to be assumed, while irregular word forms, such as *teach - taught*, are stored as wholes.

However, recently a growing body of experimental and computational studies report support for one kind of a Single-Mechanism model: the Word and Paradigm approach of morphological processing (Baayen et al., 2018; Baayen et al., 2019; Blevins et al., 2016). Word and Paradigm morphology assumes that, instead of morphemes, the word and its inflectional paradigm are the basic units of morphology. With the Naive Discriminative Learner (NDL) and the Linear Discriminative Learner (LDL) Baayen and colleagues provide two powerful computational models grounded in the principles of Word and Paradigm morphology and show for several languages (e.g. Estonian, Latin, German, Mandarin or Dutch) that computational modeling of word forms is possible

without using morphemes, further questioning the status of the morpheme as a basic unit for morphological processing.

The morphology of the Semitic language Maltese provides an interesting challenge, not only for the theoretical accounts mentioned above, but also for computational models like NDL or LDL. Maltese, the national language of the island country of Malta, developed from a Maghrebi Arabic variety and is the only Semitic language spoken as official language in the European Union. As a result of the colonial history of the island and the resulting extensive language contact with Romance languages like Italian or Sicilian and the West-Germanic language English, Maltese shows a split morphological system (Spagnol, 2011) that is for example visible in the pluralization of nouns: The singular *nazzjon* ‘nation’ has the plural form *nazzjonijiet* that is built by adding the plural suffix *-ijiet* to the singular stem. Words that are built this way are part of the concatenative morphological system of the language. Traditionally, these plurals are called *sound* plurals in Semitic languages. On the other hand, the singular *qattus* ‘cat’ has the plural form *qtates* that is not characterized by adding additional material to the singular form but instead by a rearrangement of consonants and a slight change in the vowel melody. These words are part of the non-concatenative morphological system of Maltese. In Semitic languages, these plural forms are traditionally called *broken* plurals. To further complicate matters, Maltese shows a bewildering variety of plural forms and distinguishes between 12 sound plural suffixes and 11 different broken plural patterns (Nieder, van de Vijver, et al., 2021a; Schembri, 2012).

With regard to the theoretical accounts mentioned above, the question arises how Maltese sound and broken plurals are stored and processed in the mental lexicon. Because of the split morphological system, Maltese provides an interesting testing ground for the storage of complex word forms. On a Dual-Mechanism account one needs to assume a more or less problematic distinction between regular and irregular word forms. While in a concatenative language like English irregulars are seemingly easy to detect, e.g. *goose* - *geese*, it is difficult to assess (ir)regularity in a non-concatenative language like Maltese. However, in the Dual-Mechanism literature there are different approaches on how to define the concept of regularity, e.g. Clahsen (1999) defines regularity as the default inflection while Weyerts et al. (1997) take a look at the inflections of recent loans and conclude that they are inflected according to the regular inflectional process of a language. Based on these assumptions, sound plurals need to be considered as

the regular plural operation since broken plurals only make up about 10% of all plurals in the language and recent loan words tend to be pluralized with a sound plural suffix (Borg & Azzopardi-Alexander, 1997; Camilleri, 2013).

This thesis focuses on the processing and production of Maltese plurals. In three different studies I investigated what knowledge native speakers use to build Maltese plural forms and how Maltese plurals are stored in the mental lexicon. In doing so, I tested the assumptions of Single- and Dual-Mechanism accounts on morphological processing and come to the conclusion that a word-based approach like Word and Paradigm morphology best describes the processes of generalizing to new word forms in Maltese. There is no need to assume a separate storage of complex word forms nor is there a reason to commence the daunting task of defining regularity in a non-concatenative language like Maltese. Maltese sound and broken plurals are stored as whole word forms and generalizing to new word forms is based on analogy to the stored forms, their inflectional paradigms and their frequency distribution.

The remainder of this thesis is structured as follows: Chapter 2 provides an overview of the three studies. The chapter summarizes the rationale behind the studies, the methods used in the experiments and briefly reports the main findings of each paper. The following chapters will be dedicated to the three different studies: For each study the bibliographic information and a link to the publication is given. Finally, chapter 3 will discuss the findings of this thesis and their consequences for the study of Maltese morphology and the structure of the mental lexicon in general.

2. Summary of the Publications

The first study reported in this thesis is a production experiment that investigated the knowledge of native speakers about the plural formation in their language. Following the procedure of Jean Berko's famous *wug* test (Berko-Gleason, 1958), we presented eighty adult Maltese native speakers with frequent and infrequent existing singular nouns and nonce singular nouns accompanied by pictures of existing items or fantasy animals to see if speakers make use of a default rule, or if instead the frequency of the patterns in the lexicon is the basis for generalizations. The participants were asked to provide plural forms for the given singulars. Nonce words were constructed from existing singulars by changing vowels and consonants of these words to create phonotactically legal nonce words with a different degree of resemblance to existing Maltese singulars. The suffixes and patterns participants used to inflect nonce words correlated strongly with the frequencies of the suffixes and patterns in the corpus used for the study. This indicates that the knowledge of native speakers concerning the singular-plural mappings is analogical and is determined by the frequency of the suffixes and patterns in the lexicon. Moreover, we did not find evidence for a regular rule application, such as has been proposed on a Dual-Mechanism account. We conclude, that instead the results show support for a word-based model like the Word and Paradigm approach that assumes a single mechanism for morphological processing: Sound and broken plurals are stored as wholes and new word forms are built in analogy with existing words already stored in the mental lexicon.

The second study in this thesis is a cross-modal priming experiment that investigated the storage and processing of broken and sound plurals in the Maltese mental lexicon. Based on the broken plural results reported in Schembri (2012) and the results of the production experiment in this thesis, we chose two frequent and two infrequent sound plural suffixes (*-i* and *-ijiet* vs. *-a* and *-at*) and two frequent and two infrequent broken plural patterns (*CCVVCVC* and *CCVVC* vs. *CCVjjVC* and *CCVVCV*) as materials

for this experiment. We included 144 singular targets with two types of primes: corresponding plural primes and phonologically and semantically unrelated control primes. We asked fifty-nine adult native speakers to perform a lexical decision task and recorded their reaction times. In two linear mixed effect regression models we investigated the reaction times. The results show no significant difference between sound and broken plurals. Moreover, we did not find a different frequency effect. Such a frequency effect would be expected for broken plurals on a Dual-Mechanism account. Our results show that the frequency of the plural suffixes and patterns is an important factor for accessing complex word forms in the Maltese mental lexicon. In addition, again we did not find support for a Dual-Mechanism account in this experiment, instead we conclude that the processing of Maltese sound and broken plurals is done with the same single mechanism.

The third study reported in this thesis tests the assumptions of a word-based model like the Word and Paradigm approach of morphological processing (Blevins, 2016) for Maltese with three different computational models. On the Word and Paradigm account whole words are the basic units of morphology, a reference to morphemes is not necessary anymore. Following this idea, we used Tilburg Memory-Based Learning (TiMBL) and Naive Discriminative Learning (NDL) (Baayen et al., 2011; Daelemans & van den Bosch, 2005) to classify Maltese nouns without morphemes. In a final step we used an Encoder-Decoder Network to computationally model the production of Maltese sound and broken plurals, again without providing the model with information about morphemes. Previous computational modeling of Semitic languages has highlighted the importance of the CV template for Arabic (Dawdy-Hesterberg & Pierrehumbert, 2014). Therefore, we provided a TiMBL model with information about the CV template of the Maltese nouns in our data set. The results of the modeling show that it is possible to successfully model Maltese plurals without morphemes. Moreover, the TiMBL models with and without CV template information do not show significant differences, indicating that information about the CV template does not improve the classification. Instead, information about the plural is the important factor that improves the performance of the models. Hence we conclude that the successful modeling results further support a word-based approach of morphology.

The storage of word forms in the Maltese mental lexicon is based on whole words and their inflectional paradigms.

Publications

I. Knowledge of Maltese

singular-plural mappings: Analogy

explains it best

Bibliographic Information

Author's contribution

The author of this thesis is the first author of this article and is responsible for the experimental design and the data collection for this study. Moreover, the author of this thesis significantly contributed to the statistical analysis of the results and the writing of the article.

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**II. Priming Maltese Plurals:
Representation of sound and broken
plurals in the mental lexicon**

Bibliographic Information

Author's contribution

The author of this thesis is the first author of this article and is responsible for the experimental design and the data collection for this study. Moreover, the author of this thesis significantly contributed to the statistical analysis of the results and the writing of the article.

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III. Modelling Maltese noun plural classes without morphemes

Bibliographic Information

Author's contribution

The author of this thesis is the first author of this article and is responsible for the data collection for this study. Moreover, the author of this thesis significantly contributed to the computational analysis (especially the modeling with the Naive Discriminative Learner) and the writing of the article.

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3. Discussion and Conclusion

This thesis examined the complex Maltese plural formation under the heading “Maltese Plurals: Phonotactics, Variation and the Structure of the Mental Lexicon”. While there is a growing body of literature examining several aspects of Maltese morphology (e.g. Drake, 2018a, 2018b; Geary & Ussishkin, 2018; Mayer et al., 2013; Schembri, 2012; Spagnol, 2011; Twist, 2006; Ussishkin et al., 2015, just to mention a few studies that are relevant to this work), explaining the mapping of a singular onto a plural remains a challenge, a challenge I decided to take up in this thesis.

As a Semitic language, Maltese shows signs of a non-concatenative morphological system in word formation processes. However, as Spagnol (2011) investigated in his work, the long history of language contact with concatenative languages resulted in a split morphological system. Focusing on the word formation process of pluralization only, we find that about 10 % of all plurals in the language belong to the class of non-concatenative broken plurals, while the rest of the plurals belong to the class of concatenative sound plurals (Borg & Azzopardi-Alexander, 1997). Contrary to other Semitic languages like, for example, Arabic, the Maltese language developed numerous options to build a plural of a noun, resulting in a great amount of variation in the system. This variation has consequences for the storage and processing of complex word forms in the mental lexicon.

The questions I sought to answer in this thesis were:

1. What is the knowledge Maltese native speakers use to inflect novel singular nouns?
2. How are sound and broken plural forms stored and processed in the Maltese mental lexicon?
3. Is it possible to computationally model the Maltese noun plural system without morphemes?

The first question related to what knowledge native speakers use for inflections was tested by means of a production study reported in chapter I. The study showed that knowledge of Maltese native speakers about their plural formation includes knowledge about the similarities of stored word forms in the lexicon. Maltese native speakers are able to generalize to new word forms and they use the most frequent plurals of their language to build plurals analogous to already stored word forms. The findings are in line with a Single-Mechanism model of morphology (Albright & Hayes, 2003; Daelemans, 2002; Nakisa et al., 2001; Rumelhart & McClelland, 1986; Skousen, 1992).

A Single-Mechanism account assumes that complex word forms are stored equally, independent of their morphological structure (often defined as *regularity*, for a detailed discussion about regularity see the content of the article reported in chapter II). A word-based model, such as the Word and Paradigm approach proposed by Blevins, can be described as an instance of a Single-Mechanism model since it assumes a storage based on whole word forms (Blevins, 2016). New word forms are built analogous to existing word forms and their inflectional paradigms in the mental lexicon. This is reflected in the results of the first study.

The antagonist of the Single-Mechanism approach is the Dual-Mechanism approach of morphological processing (Marcus et al., 1995; Pinker, 1998; Pinker & Prince, 1988). On this account, regular and irregular word forms are stored in different ways in the mental lexicon. While the processing of regular forms involves the application of a rule, irregular forms are stored and processed as wholes.

While the production study showed no evidence for a regular rule application in the production of nouns, thus indicating that Maltese plurals are built in the same way, the aim of the second study was to answer the second question about the organization of the mental lexicon. In doing so, the study further investigated the existence of a single mechanism for the storage and processing of Maltese nouns with a cross-modal priming experiment. The second study is reported in chapter II. We found no difference in the reaction times of our participants between sound and broken plurals. The results, again, highlight the importance of pattern and suffix frequency for the processing of Maltese nouns: The more frequent the pattern or suffix, the larger the priming effect. The absence of a significant difference between sound and broken plurals provides further evidence for a similar storage of whole word forms in the Maltese mental lexicon.

The third question is related to the assumptions of a word-based model of morpho-

logical processing. Since word-based models like the Word and Paradigm approach assume a word-based storage of word forms, a decomposition into morphemes is not necessary anymore. This can be tested with computational models, such as TiMBL, NDL or an Encoder-Decoder Network, that allow language classification and production without information about morphemes. The study focusing on the question of how to computationally model Maltese plurals is reported in chapter III. The results of this third study confirmed the assumptions of a Word and Paradigm model of morphological processing. Using the three different computational models mentioned before without morphemic information, we showed that it is possible to successfully model the classification and production of Maltese plurals without a reference to morphemes.

On the basis of the three studies presented in this thesis I argue that Maltese broken and sound plurals are stored and processed in the same way in the mental lexicon, thus confirming a Single-Mechanism model of morphology for Maltese. Neither of the three studies showed evidence for a default rule, a rule that would be used – on a Dual-Mechanism account – to inflect novel word forms in case analogy to word forms stored in the mental lexicon failed.

The findings of this thesis contribute to the growing body of literature following a word-based approach like the Word and Paradigm approach of morphological processing. Focusing on an understudied language with a bewildering amount of possible plural forms that led researchers to conclude that there are no rules – in the sense of regularities – governing the (broken) plural (Għaqda Tal-Kittieba Maltin, 1998, p.165, as cited in Schembri, 2012), I showed that there are, in fact, rules regarding the plural formation in Maltese.

The production and processing of Maltese nouns is governed by analogy to whole word forms and their inflectional paradigms stored in the mental lexicon. Not only do the results of this thesis contribute to gain a better understanding of the complex Maltese plural formation, they also question the morpheme as a basic unit for storage and processing in the mental lexicon opening a path to further research regarding the status of the morpheme in morphological theory.

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Curriculum Vitæ

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Ausbildung

- | | |
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| 2015 - 2021 | Promotionsstudium der Linguistik
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Wissenschaftliche Publikationen

- Nieder, J., van de Vijver, R. & Mitterer, H. (2021). Knowledge of Maltese singular-plural mappings. *Morphology*, 31, 147-170. <https://doi.org/10.1007/s11525-020-09353-7>.
- Nieder, J., van de Vijver, R. & Mitterer, H. (2021). Priming Maltese Plurals: Representation of sound and broken plurals in the mental lexicon. *The Mental Lexicon*, 16(1), 69-97. <https://doi.org/10.1075/ml.20008.nie>.
- Nieder, J., Tomaschek, F., Cohrs, E. & van de Vijver, R. (2021). Modelling Maltese noun plural classes without morphemes. *Language, Cognition and Neuroscience*. <https://doi.org/10.1080/23273798.2021.1977835>.

Eidesstattliche Versicherung

Ich versichere an Eides statt, dass die vorliegende Dissertation von mir selbstständig und ohne unzulässige fremde Hilfe unter Beachtung der “Ordnung über die Grundsätze zur Sicherung guter wissenschaftlicher Praxis an der Heinrich-Heine-Universität Düsseldorf” erstellt worden ist.

Düsseldorf, 22.10.2021

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Ort, Datum

A handwritten signature in black ink, appearing to be 'M. N. M.', written over a dotted line.

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Unterschrift