Morphological Processing in Older Adults.
Evidence from Russian and German

Doctoral Dissertation

Cognitive Sciences

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Introduction

Processing mechanisms and mental representations of the morphologically complex words have been actively investigated over the past decades as researchers sought to find out whether all word forms are stored in the mental lexicon and accessed as wholes or whether they are decomposed during word recognition. An additional question is whether such mechanisms are universal and to what extent they are constrained by properties of the morphological structure of the word, its nature (e.g., whether it is a derived or inflected word form) or characteristics of the particular group of speakers be it children, language learners or older adults.

This doctoral dissertation will contribute to the debate regarding types of mental representations and processing mechanisms of polymorphemic words by investigating processing of morphologically complex forms in Russian and German. Our research focus is motivated by several factors discussed in the following paragraphs.

In our view, cross-linguistic comparisons are especially useful to determine whether existing psycholinguistic theories are universal or language specific, since in the domain of morphology such theories are often based on properties of English inflectional morphology and specifically on the contrast between regular and irregular past tense forms (e.g., *played* and *tore*). However, as noted by Clahsen (2016), English past tense is actually far from being a perfect test case to examine psycholinguistic models due to many confounding factors including the total numerical dominance of -ed forms (about 95% of all forms) and the differences in morphological structure (i.e., compositional structure of -ed forms in contrast to irregular forms which do not carry overt inflectional affixes). Additionally, the degree of phonological consistency due to, for example, idiosyncratic phonological changes typical of irregular forms (e.g., *bring* - *brought*) adds additional complications.

Therefore, investigation of morphological processes in other languages is clearly needed to further inform the psycholinguistic theory and test the validity of its predictions. Such phenomena may be frequently overlooked due to the misleading application of terms coming from studies on English, which often treat various types of word forms as regular or irregular. For instance, one should distinguish between inflectional processes as in English and properties of stem-formation as in Slavic languages, including Russian. This doctoral dissertation makes a step in this direction by comparing the processing of complex forms in Russian and German.

On the one hand, we will examine processing of derived words which appear to have many similar properties in German and Russian. On the other hand, we will also study processing of inflected forms in both languages. Importantly, whilst in German we examine processing of inflected plural nouns which could be viewed as regular or irregular, Russian allows us to examine the mechanisms of stem-formation as well as the role of stem alternations in morphological processing. However, one could, perhaps, think of these contrasts between inflected forms without and with stem allomorphy in Russian and regular and irregular forms in German as illustrating the opposition between combinatorial and lexically-stored forms. This thesis examines whether, despite differences between phenomena in Russian and German as mentioned above, processing of morphologically complex forms would reflect this supposedly universal contrast between combinatorial, rule-based and lexically-stored forms.

Furthermore, processing mechanisms and representations could differ across various types of speakers as has been illustrated by studies testing groups of people for which some aspects of language processing might be more challenging. Most such studies have focused on language learners. This thesis examines yet another group which is only rarely investigated and might also struggle with some aspects of languages processing, that is older adults. As studies with language learners have shown, special populations may allow us to observe important linguistic differences, for instance, between inflection and derivation, which otherwise often remain undetected in usually tested speakers (Jacob, Heyer, & Veríssimo, 2017; Kırkıcı & Clahsen, 2013).

Moreover, studying morphological processing in ageing adults could be seen as a way to assess whether current theories informed by experimental data, mostly from college students in their mid-twenties, are universally applicable or remain largely group specific. The focus on older adults allows me to test how stable and robust posited morphological processing mechanisms and representations are and whether they change substantially throughout the lifespan. There are some indications in favour of the latter view. On the one hand, ageing is often associated with the process of cognitive decline which may also affect lexical memory (Clahsen & Reifegerste, 2017). On the other hand, ageing is also associated with substantially more experience with various word forms which may increase the efficiency of the word retrieval mechanism as assumed in several models and therefore boost existing memory representations (Reifegerste, Meyer, & Zwitserlood, 2017). The two accounts have in common that effects of age-related changes are expected to affect lexically-stored linguistic units, whereas combinatorial rule-based operations are spared. Testing older adults would therefore allow us to assess the claims concerning effects of ageing on specific processing mechanisms.

This thesis will address the issues mentioned above starting with a description of existing models of morphological processing and a review of relevant age-related changes and will then present novel experimental data in the following chapters.

1 Theoretical Background

1.1 Accounts of Morphological Processing

The investigation of the principles which define how morphologically complex words are processed has been fuelled by the opposition between connectionist-associative and symbolic-structural approaches in linguistics. As a consequence, it has led to the emergence of a number of major theories of morphological processing. In the following chapter I will review several of the most influential models as well as some of the evidence in favour of these theories.

1.1.1 Single-route models.

There are three major types of single-mechanism accounts. Whereas all single-mechanism accounts assume processing of all types of morphologically complex forms in a similar fashion, three main approaches differ in choosing a specific explanatory mechanism. These approaches include full-storage models, full-decomposition models and various types of connectionist models which will be briefly examined in the following sections.

1.1.1.1 Full-storage models.

The original model which proposed full-listing of all morphologically complex words was introduced by Butterworth (1983). According to the model all words, that is both simple and multimorphemic words, are listed in the mental lexicon as whole units. The theory argues that such whole-world access could be more efficient and impose less demands on the processing mechanism than online decomposition of complex words into morphemes during comprehension. Decomposition of complex words is treated as a fall-back option, when the primary processing strategy fails.

However, there is very little empirical support for the claims of the original full-listing model by Butterworth (1983). Recently, a new account emerged which heavily relies on whole-word representations. According to the supralexical hypothesis, whole-word representations are always accessed first so that units of a morphologically complex word such as stem and affix will receive activation from whole-word form representations and not vice versa (Giraudo, Dal Maso, & Piccinin, 2016; Giraudo & Grainger, 2001; Giraudo & Orihuela, 2015; Giraudo & Voga, 2016). The development of this approach could be traced to lexeme-based as opposed to morpheme-based understanding of morphology (Voga & Giraudo, 2009). Whereas the morpheme is the central structural unit in morpheme-based view of morphology, morphology represents a network of paradigmatic relations between words according to the lexeme-based approach. Thus, the word is seen as the core unit of the lexicon and morphological operations.

On this view, morphology is not reducible to a concatenation of morphemes which leaves out the paradigmatic dimension of complex words. As a result, it becomes natural "to assume that inflected verb forms in general, and low frequency ones in particular, are stored in the mental lexicon" (Voga & Giraudo, 2009, p. 154). Whilst the decompositional view treats morphemes as mere access units which correspond to concrete elements of words such as stems and affixes, the supralexical approach handles morphological units as more abstract due to them being placed between word-forms and semantic units (Giraudo & Dal Maso, 2016). Owing to their abstract nature these units can resist alternations (e.g., allomorphy) caused by processes of derivation or inflection. The morphemes are processed independently of their surface realizations.

A lot of experimental data on the processing mechanisms of morphologically complex words is obtained from priming experiments; see Marslen-Wilson (2007) for review. The commonly used procedure in these studies is to present a prime word prior to the target word for which a lexical decision (word/non-word) is made. The prime may be related to the target in several ways, for instance, orthographically, semantically, and/or morphologically. Morphological priming effect is found when morphologically related prime words elicit faster reaction times than unrelated primes. According to Forster (1999) this effect arises either due to the entry-opening process, whereby the prime word opens the lexical entry of the target or due to the partial pre-activation of the target. Prime words can be presented overtly or for a very brief time-window within a forward and/or backward mask to prevent their conscious recognition. The masked priming technique has been claimed to be highly sensitive to morphological relatedness at the initial stage of the access process and to tap into the rapid segmentation of complex words more directly than other priming paradigms (Marslen-Wilson, Bozic, & Randall, 2008).

Since the supralexical account stresses the role of paradigmatic relations between word forms, which is assumed to be overlooked in favor of syntagmatic dimension by decompositional views, the advocates of this approach examine the interaction of frequency effects with paradigmatic factors such as affix type and productivity[1], the role of morphological family size and other factors. In their review Giraudo and Dal Maso (2016) noted that even though the majority of experimental

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[1] Throughout this study *productivity* of an affix is understood as its ability to apply to new items including neologisms and loan words. Example of productive affixes are inflectional ending of the Past Tense in English -ed (e.g., to *blog* - *blogged*) or derivational affix -ness (e.g., *lovely* - *loveliness*).

findings was usually interpreted as evidence of automatic decomposition, they are also in line with holistic models of lexical architecture.

For instance, Giraudo and Orihuela (2015) examined processing of derived words (e.g., *mariage-marier* 'wedding – to marry') using the masked priming paradigm. They also manipulated relative surface frequency of the derived primes with half having a higher surface frequency than base word targets and the other half having a lower frequency. The approach which insists on automatic decomposition would predict facilitation for both types of derived words from prior presentation of a morphologically related word. However, the results disconfirmed this prediction, showing priming effects only after high-frequency primes and no benefit from presentation of the low-frequency primes followed by a target word with higher surface frequency. Thus, despite the salience of the base word forms, authors observed surface-frequency interference effect. The presence of this effect indicates the role of the whole-word properties which override properties of its subparts.

Giraudo et al. (2016) conducted a similar experiment in Italian. However, they kept the frequency of primes constant and manipulated the stem frequency of the base targets. The facilitation effect was induced irrespective of the frequency of targets or the frequency of the base contained in the primes. Moreover, the authors reported full priming effects in both of the examined groups, that is similar response latencies to target words following identity and related primes and significantly slower response latencies following unrelated primes. These findings were interpreted as evidence against the decompositional approach since the base frequency did not interact with the priming and thus there was no evidence of a segmentation process at a prelexical level.

Another piece of evidence comes from a study investigating inflection in French by Voga and Giraudo (2009). They have conducted two experiments manipulating prime-target configurations. They assumed that if the competition during morphological processing takes places, then morphological priming should be more robust for items with a small number of competitors (i.e., words sharing the same letters as the stem). Robust priming effects were found when targets were infinitives and thus could be easily activated due to having the highest frequency in a paradigm and hence, a lower activation threshold. The prime effects under such conditions were not modulated by the number of competitors. However, the role of the 'environment' plays a role when targets cease to be the easiest-to-activate form. Voga and Giraudo (2009) reported an absence of a priming effect for low-frequency targets in the presence of many competitors which interfere with the processing of such forms.

The role of the lexical competition along with the findings from the studies reported above (the role of surface frequency) investigated by means of the masked priming paradigm suggest the importance of paradigmatic relationships for the processing mechanism. As previously mentioned, these views are arguably easier to reconcile with models of morphology which view lexemes instead of morphemes as core units of processing. Thus, even though the original whole-listing model developed by Butterworth (1983) lacks empirical evidence and appears to be outdated, some of its ideas can be found in more recent theories. An example for this is found in the supralexical theory of processing, which considers whole-word processing to play a major role especially during initial stages of word recognition.

1.1.1.2 Full-decomposition models.

A totally different view on processing mechanisms of morphologically complex words is espoused by the proponents of the full-decomposition models. Full-parsing accounts support a view that a complex form recognition is achieved via decomposition of a word into its constituents or, in other words, via isolation of morphemes and by gaining access to its meaning (Taft, 1979; Taft & Forster, 1975). According to this approach, only affixes and stems are expected to be stored in the lexicon. The obligatory decomposition of surface forms could lead to the isolation of even non-existent stems such as 'proach' (from *'approach* and '*reproach*') and 'suade' (from *'dissuade'* and *'persuade'*) which are listed as entries in the lexicon. Thus, morphemes are viewed as core units of lexicon organisation.

The full decomposition of complex words is considered to be a default route for processing polymorphemic words and especially transparently affixed words (Taft, 2004). While the original model considered decomposition to be obligatory during early stages of processing, later models also include an additional model of representation namely the lemma level (Taft, 2004; Taft & Nguyen-Hoan, 2010). Lemma level contains representations of both free and bound morphemes. Whereas fully transparent word such as *reheating* do not possess their own lemma, other words such as *feathery* do. This happens due to the fact that all information about the former type of a word could be computed based on its constituents, whereas the latter type is associated with more specific information irreducible to the combined meaning of its stem and affix.

This model assumes two stages of processing with obligatory decomposition at the input stage followed by a later stage of recombination of specific information associated with extracted stems and affixes. Since the model assumes obligatory decomposition of at least transparently affixed words, observing the base frequency effect is of paramount importance to this model. The absence of such effects as found in several studies including by Giraudo et al. (2016) may therefore pose a problem. However, as Taft (2004) notes, absence of such an effect does not necessarily imply absence of the combinatorial processing, as it can be masked by counterbalancing influences at a later stage. For example, for forms such as *moons* which are usually used in singular, later recombination processing may be more demanding than for words like *cliffs*. Even though the base frequency of the word *moon* is higher than that of the word *cliff*, this advantage is neutralized at the stage when functional information associated with the stem has to be combined with the information associated with the suffix.

The evidence supporting this approach comes from several experimental techniques including the masked priming paradigm. This method employed in a variety of studies is often taken to demonstrate the application of blind morphological procedures as not only truly derived words such as *reader*, but also words which only *appear* to have a derivational affix such as *corner* also lead to a facilitation effect (Rastle, Davis, & New, 2004). Further studies demonstrated that this facilitation effect is morphological in nature and is not reducible to simple semantic and orthographic overlap, because words such as *broth* were effective primes of *brother* but not *brothel*. Even though both targets are morphologically simple, the word *brother* resembles complex words having *–er* affix, while the word *brothel* does not, as there is no *–el* affix in English (Rastle & Davis, 2008).

Similarly, Longtin, Segui, and Hallé (2003) reported a facilitation effect in French not only when words were truly morphologically related (e.g., *gaufrette* 'wafer' – *gauffre* 'waffle') but also when the relationship was morphologically opaque (e.g., *fauvette* 'warbler' – *fauve* 'wildcat'), and, crucially, when a prime was a pseudo-derived word (e.g., *baguette* 'little stick – *bague* 'ring'). Moreover, morphologically structured nonwords were also found to facilitate existing targets with the same affix (e.g., *treasonism – alcoholism*) which could be explained as reflecting activation of constituent morphemes (Crepaldi, Hemsworth, Davis, & Rastle, 2016). Taken together, these findings may indicate that if primes are shown very briefly so that little information about the word could be extracted, the decomposition mechanism is applied to all morphologically structured stimuli or even to stimuli which only appear to be morphologically structured.

Whereas earlier described decomposition-based models were mostly applied to transparently affixed (or pseudo-affixed) forms, a different model by Stockall and Marantz (2006) predicts across-board decomposition. An example are forms such as *taught* or *sprang* in English which are considered to be irregular. Morris and Stockall (2012) claim that processing of forms such as *taught* in English is achieved via activation of the root *teach.* This activation occurs via recognition of 'the surface [ɔt] sound (or *aught* letter string) as the output of a rule that operates over underlying /itʃ/ sequences' (Morris & Stockall, 2012, p. 82). Thus, generation and recognition of allomorphs is also rule-based even though these rules apply to the restricted set of roots.

The behavioral data from the masked priming experiment on English has produced a full priming for regular -ed past tense forms (i.e., the same response latencies to the target word following presentation of the identity prime and related prime and faster response latencies to target words after related primes than after unrelated ones) and partial priming for irregular forms (i.e., faster response latencies in the latter case to target words after related primes than after unrelated primes but slower than after identity primes). However, it was hypothesized that this dissociation may reflect late stages of processing. Analysis of the recorded electrophysiological data and specifically ERP (event-related potential) components implicated in masked priming showed that related and identity primes were equally effective in reducing the amplitude of the two early negative deflections around 250ms (N250) and at around 400ms post target (N400) regardless of the verb type. This finding was interpreted as evidence in favor of the early decomposition-based processing mechanism.

However, the automaticity and potential blindness of the decomposition mechanism becomes also a theoretical problem, since the purpose of parsing *corner* into *corn* + *er* remains hard to explain if morphology captures form-meaning correlations (Crepaldi et al., 2016). There is indeed a family of the connectionist and associative models which question the relevance of the morphological level and the role of morphemes as fundamental units in the representation of language. These models will be reviewed in the next section.

1.1.1.3 Connectionist models.

The concept of explicit morphological level of processing is often criticized by the proponents of many associative single-mechanism models. The meaning of a complex polymorphemic form can be retrieved directly, as all forms of a word are stored within a single memory network and are interconnected by associative links. Under this view, processing of regular and easily decomposable forms and irregular forms employs the same mechanisms (MacWhinney & Leinbach, 1991; Marchman, 1993; Plunkett & Marchman, 1993; Rumelhart & McClelland, 1986).

In support of their claims researchers build computer models trying to simulate processes in the human brain and findings observed in behavioural studies. They reject explicit symbolic rules in favour of supposedly more plausible mechanisms. Explicit rules are considered to be useful only as a descriptive tool (Bybee, 1995; Marchman, 1997). This approach became widely adopted after the initial success of several models, for example by Rumelhart and McClelland (1986) and MacWhinney and Leinbach (1991). The aim of these models was to simulate acquisition of the English verbal system.

A modification of associative-memory model utilizes several levels of representations including phonologic and semantic components (Joanisse & Seidenberg, 1999, 2005; Kielar, Joanisse, & Hare, 2008). Joanisse and Seidenberg (1999, p. 7593) provide the following Figure 1 representing the associative-memory model:

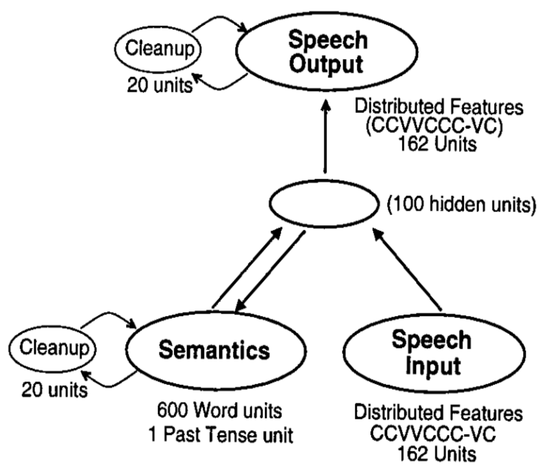

Figure 1. Model architecture. Ellipses represent groups of units. Arrows represent connections between groups and the direction of information flow. Reprinted from "Impairments in verb morphology after brain injury: A connectionist model", by M.C. Joanisse and M.S. Seidenberg, 1999, *Proceedings of the National Academy of Sciences*, 96, p. 7593. Copyright 1999 by National Academy of Sciences.

In the model above "words were represented in terms of the codes involved in the past-tense generation task: speech input (a representation of the sounds of words), speech output (a code produced in generating speech), and semantics" (Joanisse & Seidenberg, 1999, p. 7953). Speech output and input were coded as distributed phonological representations. Many models including the one above by Joanisse and Seidenberg (1999) also have one or several additional layers of hidden units which transform the input pattern via changes in the connection strengths and could learn complex input/output relationships (Schneider, 1987). Due to hidden unit learning algorithms[2] such models are arguably able to construct abstract internal representations and develop emergentist properties unlike two-layer networks which would directly link the input units to the output units (Rumelhart, Hinton, & Williams, 1986; Schneider, 1987). For instance, two-layer networks would not be able to succeed in tasks which require the classification of featurally dissimilar words as belonging to one abstract category because such models would rely solely on the input-based similarity (Hare, Elman, & Daugherty, 1995). In the model by Joanisse and Seidenberg (1999) the semantics and spoken output layers are linked to so called "cleanup" layers which function as additional hidden units and "help semantics and output phonology settle into correct … states" (Plaut, 2003, p. 156) by "cleaning up" the noisy or inaccurate patterns.

Joanisse and Seidenberg (1999) trained the presented model to perform generation of past tense forms in English. After 2.6 million trials the accuracy of the network reached 99.3% on the trained set and 90% on the set of novel verbs compared to the actual production data by healthy control subjects as reported by Ullman et al. (1997). Thus, even though the model did not posit separate processing mechanisms for regular versus irregular morphology, it was able to process both types of verbs. The processing advantage for regular forms which is often reflected, for instance, in larger magnitudes of priming is argued to arise due to the greater phonological and orthographic overlap of regular forms compared to irregular forms (Joanisse & Seidenberg, 1999; Kielar & Joanisse, 2010). During processing of irregular items semantics is claimed be more heavily involved in mapping various forms of irregular verbs to their stems.

This approach is presumably able to account for various brain injury phenomena (Howell, MacDonald, & Seidenberg, 2014) which were otherwise considered to demonstrate existence of two separate mechanisms for processing regular and irregular forms (see more in Chapter 1.1.2 on Dual-Route models). For example, the study by Ullman et al. (1997) examined performance of Alzheimer's disease (AD) and Parkinson's disease (PD) patients in production of past tense forms from regular, irregular and novel verbs. It was observed that severely affected PD patients had significant troubles generating correct past tense forms for novel and regular. In contrast AD patients experienced more problems inflecting irregular verbs. This performance was taken by Ullman et al. (1997) to indicate that irregular forms are processed via a memory-based mechanism

[2] One of such algorithms is the backpropagation of error learning algorithm (Rumelhart, Hinton, & Williams, 1986) which calculates the output error, i.e. the difference between the actual output and the desired output, and sends error signal back down to adjust the connection weights of the hidden units

which is presumably impaired in AD patients, whereas regular and novel forms are processed by a rule-based combinatorial mechanism which is impaired in PD patients.

Based on the model introduced earlier (see Figure 1) Joanisse and Seidenberg (1999) argue against two separate processing mechanisms. Their model is also able to reproduce the observed deficits of AD and PD patient groups by simulating semantic or phonological impairments respectively. These deficits were simulated by severing 10% of connections to and from semantic or phonological cleanup layers and adding Gaussian noise. To test the effect of these lesions Joanisse and Seidenberg (1999) used the same regular, irregular and nonword verbs as Ullman et al. (1997).

According to Joanisse and Seidenberg (1999) the model with severed connections to the semantic cleanup layer was able to accurately simulate lower accuracy of AD patients in producing forms of irregular verbs as reported by Ullman et al. (1997) whereas the poorer performance of PD patients on regular and novel verbs was replicated when the number of severed connections to and from the speech output's cleanup layer was increased. Joanisse and Seidenberg (1999) also noted that a semantic deficit also led to a higher number of overregularizations of irregular verbs (e.g., **keeped* instead of *kept*) whereas phonological deficit increased the number of irregularization errors (e.g., **boke* instead of *baked*).

To explain performance of the model Joanisse and Seidenberg (1999) reflected on the properties of regular and irregular verbs. Due to the inconsistent phonological relationship between past and present forms irregular verbs are less dependent on phonological component and arguably rely more on support from a semantic component which is involved in learning idiosyncratic word-specific information. As a result, disruption to the network's semantic component would heavily affect the ability to generate past tense forms from irregular forms which would then pattern with phonologically similar verbs, such as *tame* or *fake* in case of *take* leading to overregularization errors (Joanisse & Seidenberg, 1999). Conversely, due to the highly consistent phonological relationship between past and present tense forms of regular verbs, they are argued to rely more on a phonological component. As a result, lesions to phonology would interfere with the ability of the model to correctly produce regular past tense forms. Thus, the connectionist model by Joanisse and Seidenberg (1999) was able to fully replicate experimental data reported by Ullman et al. (1997) as being due to the damage to either semantic or phonological representations without having to assume two distinct processing mechanisms responsible for regular and irregular forms.

A modified single-mechanism account is pursued by Joan Bybee and colleagues (Bybee, 1995, 1996; Bybee & McClelland, 2005; McClelland & Bybee, 2007). The word forms are related to each other via common phonological and semantic features. Moreover, connections emerge even between forms derived from various stems. This approach allows determining the morphological structure of a word without explicitly postulating a separate morphological level of processing. Figure 2 shows how, for example, a regular affixation could be represented within a network via sets of lexical connections (Bybee, 1996, p. 249):

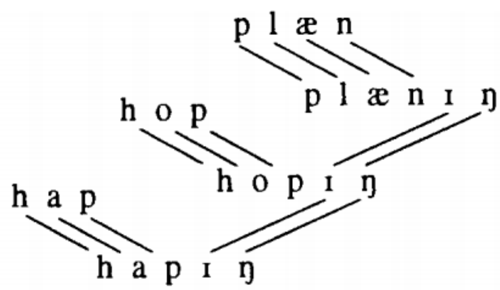

Figure 2. A network representation of regular affixation. Reprinted from “Productivity, regularity and fusion: How language use affects the lexicon”, by J. Bybee in R. Singh (Ed.) *Trubetzkoy’s Orphan*, p. 246, 1996, Philadelphia: John Benjamins Publishing. Copyright 1996 by John Benjamins Publishing Company.

The irregular verbs, for example, vowel change verbs such as *cling – clung*, *sting – stung* and *stick – stuck* would be represented in the same way by means of lexical connections.

High frequency of the derived word weakens mapping between it and a base word as the high-frequency derived word accumulates more lexical strength and becomes more autonomous. Hence, such high-frequency forms will be stored unanalysed by means of rote learning. Traces in memory left by infrequent forms are much less salient and as a result semantics and phonology should be more involved in the recognition process according to Bybee (1995).

Crucial to Bybee’s account of morphology is the notion of schema. The schema is understood as an “emergent generalisation” over a set of “words having similar patterns of semantic and phonological connections” (Bybee, 1996, p. 249). High type frequency enhances the mapping between forms which leads to a generalization of schemas and increase in productivity of a particular schema. Under such view, analogy-based schema which is influenced by similarity and frequency replaces traditional rules. In the model by Bybee (1995) processing rate of a word is defined not by a set of explicit rules. It depends on several factors such as type and token frequency, productivity of a schema and others, which are conditioned by a functioning of a linguistic unit in language. Effectively, it is a usage-based model.

However, the majority of analogy-based connectionist models could be presumably criticized for several reasons. For instance, Baayen (2014) points out that a lot of models including the one by Joanisse and Seidenberg (1999) discussed here or the one by Plaut and Gonnerman (2000) introduce special layers of hidden units and the number of such layers as well as the number of hidden units are often poorly motivated. The same criticism could also be made concerning implemented feature representations of phonology, orthography and semantics according to Baayen (2014). Furthermore, another problem is that it is often necessary to construct a new model to account for each individual phenomenon, be it processing of past tense forms or allomorphy of plural affixes etc. (Baayen & Ramscar, 2015). The naïve discriminative learning model (NDL) developed by Baayen, Milin, Đurđević, Hendrix, and Marelli (2011) attempts to overcome these weaknesses.

NDL is based on the error-driven learning mechanism which “governs success in adaptation to an environment by iteratively correcting erroneous predictions for upcoming events” (Milin, Divjak, Dimitrijević, & Baayen, 2016, p. 510). This learning system relies on input cues and outcomes as well as the weight of connections between them as crucial components. The weight changes as a result of experience such that its strengthening reflects learning. Baayen and Ramscar (2015, p. 110) provide in the Figure 3 the example of the model with five digraphs as cues and three lexemes as outcomes:

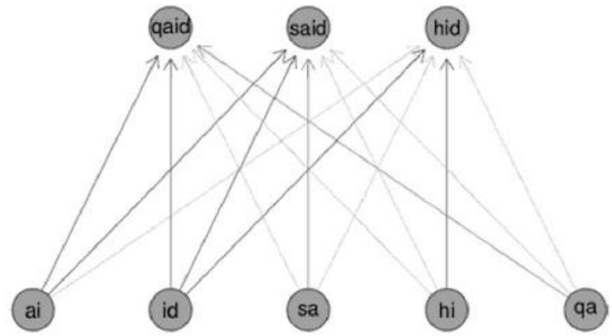

Figure 3. A network with five bigrams as cues and three lexemes as outcomes. Reprinted from “Abstraction, storage and naive discriminative learning”, by R.H. Baayen and M. Ramscar in E. Dabrowska and D. Divjak (Eds.), Handbook of Cognitive Linguistics, *39*, p. 110, 2015, Berlin, Boston: De Gruyter Mouton. Copyright 2015 by Walter de Gruyter GmbH.

The authors argue that the bigram *qa* allows to unmistakably identify the word *qaid* and hence is strongly associated with this word while being negatively associated with two other words. The *id* bigram is found in all three lexemes and thus it does not allow to predict with certainty any of the words which is reflected in small weights on its connections. The activation of the word represents the summation over the weights from its orthographic cues to its lexemes.

The NDL model using only letter unigrams and bigrams as input cues and “content” as well as “grammatical lexemes” (such as number and tense) as outcomes was allegedly able to simulate results found in behavioral studies including word frequency, morphological family size effects and others. For example, Baayen et al. (2011) have applied the network architecture to the words in the British National Corpus and have calculated the activation for any given word by summing the weights from its orthographic cues or for words with multiple lexemes (e.g., plurals or compounds) by summing activation of its lexemes. These values were then pitted against the average lexical decision latencies available in the English Lexicon Project (Balota, Cortese, Sergent-Marshall, Spieler, & Yap, 2004). Activation weights were able to predict the lexical decision times, that is words which elicit slower responses correspond to the words with lower activations. It was assumed that this reflects poor learnability of such words based on their orthographic properties (Baayen & Ramscar, 2015).

The authors also analyzed inflected verbs in English having included the (uninflected) present and past-tense plural forms (*walk, walked, come, came*). The linear mixed effects models to the observed and simulated RTs[3] have produced similar coefficients for predictors such as frequency, family size, neighborhood density, length and importantly tense (present vs. past), regularity (regular vs. irregular), and their interactions. For both datasets Baayen et al. (2011) observed substantial differences in response latencies between present and past-tense irregulars forms whereas for regular forms response latencies were similar.

The NDL model is putatively advantageous compared to previous models considering its simpler architecture devoid of any hidden units typical for other connectionist models. However, it was also criticized as it is unclear how n-grams could be acquired (Plag & Balling, 2016). Furthermore, Marantz (2013) claims that the model implicitly builds morphology into its semantic layer. Baayen et al. (2011), for instance, examine inflection in Serbian and assume that the summed activation of the lexical meaning and grammatical meaning for number and case predict its processing time. Essentially, this means that each noun is assigned one meaning from the number set and one from the case set. According to Marantz (2013, p. 912) this is an unmistakable example illustrating integration of the morphological structure typical of "Serbian noun into the ''semantics'', demanding a number and case marking along the syntagmatic dimension and requiring only a single instantiation of the number and one of the case along the paradigmatic dimensions".

To sum up, single-mechanism models described above consider the morphological structure as an emergent property observed due to semantic and phonological connections found in multiple sets of words. Thus, morphemes are denied an independent status in the mental lexicon in contrast to, for example, full-parsing models (Plaut, 2011). As a consequence, distinction, for instance, between regular and irregular forms or between inflection and derivation becomes superficial for a large family of single-mechanism approaches since core processing mechanisms are identical no matter what the nature of a particular complex word is.

1.1.2 Dual-route models.

A radically different view on the nature of morphological processing is represented in studies supporting dual-route models. Contrary to connectionist theories, morphological structure is not considered to be a mere byproduct of form-meaning correspondence. The language in general is

[3] "the simulated RT was defined as the log-transform of the reciprocal of the probability of identification of a word in the set of its most highly activated competitors" (Baayen, Milin, Đurđević, Hendrix, & Marelli, 2011, p. 44)

assumed to include two core components, that is a lexicon to store idiosyncratic linguistic knowledge and a computational system that underlies construction of linguistic units by means of regular combinatorial operations. Many dual-routes models including the so called Words and Rules theory (henceforth WR) originally introduced by Pinker (1999) predict different processing mechanisms of regular (*default*)[4] and irregular forms and were initially applied to account for processing of English past tense forms. Thus, it was hypothesized that regularly inflected -ed forms are generally decomposed in real time into their constituents (*walked – walk + -ed*), whilst irregular forms such as *taught* are listed in the lexicon as whole-word representations and directly retrieved from the memory (Marcus et al., 1992; Pinker, 1998, 1999; Pinker & Prince, 1988). The processing mechanisms are represented in the following Figure 4 (Pinker & Ullman, 2002, p. 457):

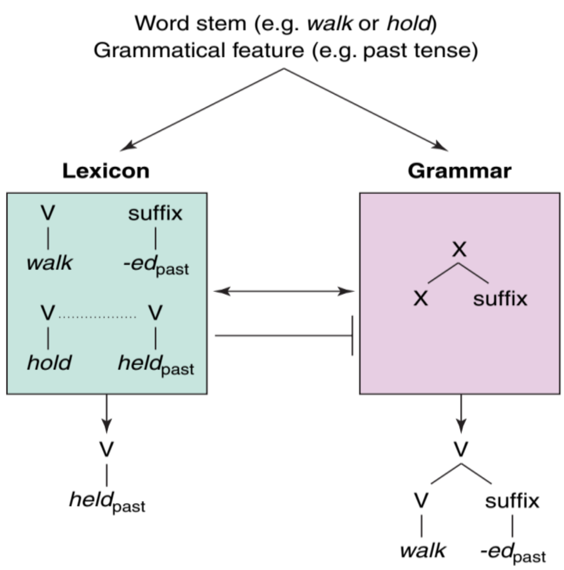

Figure 4. Illustration of the Words-and-Rules (WR) theory and the Declarative/Procedural (DP) model. Reprinted from “The past and future of the past tense”, by S. Pinker and M.T. Ullman, 2002, Trends in Cognitive Science, 6(11), p. 457. Copyright 2002 by Elsevier Science Ltd.

[4] For the purpose of this study the pattern is considered to be *default* if it is applied when “access to lexical memory is ruled out, in cases such as nonsense words that are dissimilar to existing words, derived forms, and words that do not have canonical lexical entries” Clahsen (1999a, p. 1004). Following Clahsen (2016) we apply this term to inflectional morphology, for example, -ed affix in English and to stem-formation morphology such as 1st conjugation in Italian (e.g., *[[ama]-a]* from *amare* which is a combination of a root and a theme vowel).

The inflection of the polymorphemic words in production is posited to proceed as follows. The first step presupposes simultaneous activation of both processing mechanisms. Next, the rule-based mechanism and the memory-based retrieval mechanism compete as the lexical search tries to retrieve a word from the associative memory while rule-governed parser relies on decomposition. A successful lexical look-up blocks application of the symbolic rule by the procedural memory indicated by the inhibitory link in the figure from lexicon to grammar (Pinker, 1999; Pinker & Ullman, 2002). This prevents forms such as *holded*. If no match in the lexicon is found, a regular[5] form is generated by concatenation of the stem and the affix. Several factors may also presumably prevent direct access of a word, including low surface frequency of a word, atypical sounding patterns, certain contexts (e.g., a verb ‘to ring’ is irregular when denoting ‘to call’ and is regular when it means ‘to encircle’).

The memory system underlying mechanism of storage could be structured similarly to connectionist models (Ullman, 2001). Therefore, the strength of connections among units begins to play an important role which accounts for surface frequency effects of irregular verbs. As a result, higher frequency improves the processing rate of irregular verbs. As regular polymorphemic words were supposed to undergo decomposition in WR model, surface frequency of a form was initially deemed to be irrelevant as it lacked a representation in the mental lexicon. However, a study by Alegre and Gordon (1999) challenged this assumption by revealing sensitivity of some regular and decomposable verbs to the surface frequency. This finding had implications for the dual-route models which started to allow the lexical storage of high frequency regular forms as well.

The existence of different mechanisms responsible for storage and computation is considered to be biological in nature (de Diego Balaguer et al., 2006; Jaeger et al., 1996; Marslen-Wilson & Tyler, 1998; Münte, Say, Clahsen, Schiltz, & Kutas, 1999). One of the most influential models which relies on distinct neurobiological systems is the Declarative/Procedural model (DP) developed by Michael Ullman (Ullman, 2001, 2016; Ullman & Pullman, 2015). According to this model, language is subserved by two well-established memory systems: declarative memory and procedural memory.

In this model declarative memory plays a crucial role in storing and processing arbitrary and idiosyncratic information including irregular morphological forms either inflectional or

[5] The notions of *regularity* and *defaultness* were often used interchangeably by the proponents of the dual-route models to describe properties of inflection in English and German. However, in line with Clahsen (2016) we will refrain from using the term *regular* to describe stem-formation processes. The distinction *regular* vs. *irregular* will be, thus, applied in this thesis only to characterize inflectional processes. Stem-formation morphology will be rather treated in terms of being combinatorial, allomorphic (e.g., *salg-o* ‘leave 1P.Sg.Pr.’ from *salir* in Spanish) or suppletive.

derivational, idioms, proverbs etc. (Ullman, 2016). Moreover, nothing precludes storage and memorization of completely regular and rule-based forms as well (Ullman, 2001). In general, though, completely regular forms are processed by procedural memory which is posited to underlie rule-based computation of hierarchical sequences. This involves real-time computation of morphological transformations such as concatenation of bases and affixes (e.g., *rat*+ -s – *rats, employ* + *-ment* – *employment*). The declarative/procedural model developed by Ullman (2001) can be seen as an extension of the WR model "to a hypothesis about the neurocognitive substrate of lexicon and grammar" (Pinker & Ullman, 2002, p. 457).

The interaction between storage and decomposition is a highly controversial issue and models differ substantially in defining criteria which affect the choice of a mechanism. For example, one of the earlier models such as the Augmented Addressed Morphology (AAM) model holds that whole-word direct access is more efficient than decomposition-based parsing for all complex words except for novel and unfamiliar words (Caramazza, Laudanna, & Romani, 1988; Chialant & Caramazza, 1995). The polymorphemic words are assumed to have their own form-level representations. The claim regarding morphological decomposition of only unfamiliar forms was later revised. It was suggested that the low familiarity should not be necessarily conceived of in terms of the low absolute frequency. Instead, parsing route may outperform whole-word retrieval mechanism when stem frequency is higher than the surface form frequency. This hypothesis implies both processing routes are activated "to an extent which is directly proportional to the frequency of the access unit" (Chialant & Caramazza, 1995, p. 63). Thus, morphologically decomposed representations are allowed for inflected words even though the whole-word access is treated as a faster route and is preferred.

The assumption of the parallel activation of two processing mechanisms and competition among them is crucial to yet another approach known as a "horse-race" model (Baayen, Dijkstra, & Schreuder, 1997; Schreuder & Baayen, 1995). While irregular forms are stored, the balance between storage and decomposition for regular forms is not determined a priori. The winning route is established by several factors such as surface frequency, semantic transparency of a complex word as well as the polyfunctionality of its affix (Bertram, Laine, & Karvinen, 1999; Bertram, Schreuder, & Baayen, 2000). To illustrate their point, Bertram et al. (2000) investigated processing of complex words in Dutch with derivational *-er* used to produce nouns (as in *open* – *opener* or *work* - *worker*) which has an homonymous inflectional rival used to produce comparatives (as in *strong* - *stronger*). In the unprimed lexical decision task the differences in response latencies were found for high and low surface frequency derived forms. For the *-heid* derivational affix which has no homonymic rival affixes only the base frequency effect was found. The authors interpreted these findings as indicating that presence of the strong inflectional rival *-er* shifted the balance in favor of storage.

In general, Bertram et al. (2000) suggested a decision tree according to which productivity of the affix plays a crucial role. Words with unproductive affixes are going to be stored. Alternatively, homonymity places a role inducing storage if rival affixes with a different semantic function exist. If there are no such affixes Bertram et al. (2000) refer to the notion of the meaning-invariant (e.g., person and number marking on verbs) versus meaning-changing (e.g., subject-noun formation) morphology to determine which route is likely to win. On the whole the "horse-race" model appears to take more factors into account than WR (or similar declarative/procedural model) which tends to focus on regularity of the word.

Yet another model would, similarly to the WR and DP models, predict differences with regard to, for example, English regular and irregular past tense forms such as *played* and *gave*. However, unlike in the WR model the difference is not due to the regularity and irregularity of the forms *as such* but rather due to their compositionality (Marslen-Wilson & Tyler, 1997, 2007; Post, Marslen-Wilson, Randall, & Tyler, 2008). While forms such as *played* allow segmentation into a corresponding stem and an affix, this is not possible for the forms such as *gave* which have to be stored and accessed in the same way as morphologically simple words (Marslen-Wilson & Tyler, 2007). The difference between two forms arises due to word properties which either allow process of phonological assembly (or disassembly, in comprehension) or not.

While models such as WR and the one presented above may be comparable with regard to expecting processing differences between forms such as *played* and *gave*, the dissimilarity becomes apparent in other cases. As the model by Post et al. (2008) expects parsing of all inflected forms, while the WR and declarative/procedural model would assume segmentation of only regular forms, different outcomes are predicted, for example, for German *-en* (irregular) participles such as *geschlafen* "slept". Smolka, Khader, Wiese, Zwitserlood and Rösler (2013) argue that such participles are not predicted to be decomposed in the WR model due to their irregularity in German, but should be parsed into their constituents following the model by Post et al. (2008). It should be noted that this claim remains controversial due to the conflicting findings for irregular -en and regular -t participles in German (Smolka, Zwitserlood, & Rösler, 2007; Sonnenstuhl, Eisenbeiss, & Clahsen, 1999).

While various single-route models deny existence of distinct mechanisms underlying processing of easily decomposable, regular forms and idiosyncratic irregular forms as well as distinction between inflection and derivation, differences between inflectional and derivational processes are examined in more detail within the dual-route models. It could be assumed that as both derived and regularly inflected words are constructed by means of abstract combinatorial operation (rules) they differ from irregular forms which are stored in the mental lexicon. This was indeed true in the WR model. However, some researchers paid attention to some critical differences between inflectional and derivational processes (Clahsen, Sonnenstuhl, & Blevins, 2003).

Whereas derivation produces new lexemes which can undergo further word-formation including feeding new derivational or inflectional processes (e.g., *read → readable → readability*), inflection produces only word forms (e.g., plural forms as in *reader → readers*) (Anderson, 1992). Hence, both a derived form (e.g., *reader*) and a base form (e.g., *read*) could be listed in the mental lexicon. At the same time, recognition of the derived word may supposedly also rely on access to its morphological structure since similarly to regularly inflected forms it was formed by application of the productive rule (e.g., *read → reader*). As a consequence, this implies activation of the underived stem (Clahsen et al., 2003). The similar view is expressed in Marslen-Wilson (2007, p. 189) who noted that "despite early identification of morphemic structure, for both transparent and opaque derived forms, it is unlikely that this leads to a disassembly of the complex form into its morphemic components". This disassembly is hardly possible due to the noncompositional meaning of many derived words.

In essence, a modified version of the dual-route model developed by Clahsen et al. (2003) assumes a tripartite difference between following linguistic elements: (a) productively derived entries (b) productively inflected forms and (c) frozen unanalyzed forms (for irregular inflection and nonproductive derivation). If these theoretical hypotheses are true, the differences are expected to be observed in the experimental studies as well.

1.2 Processing of Inflectional Morphology

In this chapter I will review several important findings concerning processing of inflected words. The majority of the findings discussed below comes from languages other than Russian and German, since studies on these languages will be reviewed in greater depth in relevant chapters.

A lot of experimental data on the processing mechanisms of inflected forms is obtained from priming experiments. The first study to mention a morphological priming effect examined processing of past tense forms in English by Stanners, Neiser, Hernon and Hall (1979). The authors observed a full priming effect for regular forms such as *played*, that is the same response latencies to the target word *play* following presentation of the identity prime *play* and related prime *played*. In contrast, response latencies for irregular verbs (e.g., *gave - give*) were significantly slower in the test condition than in the identity condition, though still faster than in the unrelated condition, therefore producing a partial priming effect. These findings were interpreted in favor of two distinct types of representations for verbs. It was assumed that while there are no separate lexical representations for the inflected forms of regular verbs which are decomposed into stem and -ed affix, irregular forms are stored as separate lexical entries. The priming is only partial for such verbs since activation should spread between the inflected irregular form and its base verb. Irregular verbs themselves do not constitute a homogeneous group and may be processed differently. A study by Marslen-Wilson et al. (1993) demonstrated that verbs such as *kneel – knelt* with vowel changes and -t as the final consonant yielded no facilitation effect, whereas irregular verbs with a vowel change and without *–t* affixation (e.g., *drive→ drove*) elicited slower RTs compared to unrelated prime-target pairs.

The evidence in favor of the dual-route account came also both from neuroimaging studies (Beretta et al., 2003; de Diego Balaguer et al., 2006; Jaeger et al., 1996) with distinct activation patterns for regular and irregular forms and ERP studies where regular and irregular verbs showed dissimilar type of waveforms (Rodriguez-Fornells, Münte, & Clahsen, 2002). However, the observed patterns should not necessarily imply two distinct processing mechanisms. Seidenberg and Arnoldussen (2003) argue that the single mechanism connectionist approach does not refute existence of the differences between regular and irregular forms. As Seidenberg and Arnoldussen (2003, p. 528) put it “the question is not whether regular and irregular forms differ but why”. The single-mechanism models attribute observed differences to the role of various linguistic components. One possibility is the larger role of phonological component in processing of regular forms due to strong phonological regularities, whereas the semantic component is more involved in recognition of irregular forms. This claim is arguably supported by the findings from the studies of language disorders (Bird, Ralph, Seidenberg, McClelland, & Patterson, 2003; Joanisse & Seidenberg, 1999; Ralph, Braber, McClelland, & Patterson, 2005).

In addition to the misinterpretations of the single-mechanism approach, studies such as by Beretta et al. (2003) which presumably show different activation patterns for regular and irregular forms and argue in favor of the dual-route mechanisms are controversial as well. Beretta et al. (2003) reported greater activation only for irregular forms in frontal and posterior temporal regions, but no greater activation for regular forms in any region. Seidenberg and Arnoldussen (2003) as well as Joanisse and Seidenberg (2005) claim that this single dissociation is likely to be due to the unmatched difficulty of the stimuli, that is irregulars being more difficult to process that regular forms. The greater activation for irregular forms could simply reflect the increased task difficulty.

The conflict between the single-mechanism and the dual-route models motivated investigation of comparable phenomena in other languages to test cross-linguistic validity of the proposed processing mechanisms. Such studies focused on Romance languages with conjugational classes absent in English. The studies will be reviewed below in greater detail as one can compare conjugational classes in Romance languages to Russian examined in the present study.

Meunier and Marslen-Wilson (2004) investigated the processing of inflected forms in French. There are three conjugational classes. The 1st class which includes verbs with infinitives ending in -er is the most productive and regular. The infinitives of the 2nd class end in -ir. This class is no longer productive but fully regular. The 3rd class includes verbs which are highly irregular. Despite an abundance of stem allomorphy inflectional paradigms remain regular. Conducted cross-modal and masked priming experiments yielded similar facilitation effects for all verbs (fully regular, regular with phonologically triggered changes, subregular and irregular). Meunier and Marslen-Wilson (2004) claim that these data run against the dual-route model which would predict reduced priming following allomorphic primes postulating a separate representation of the allomorphic stem in the lexicon. The results fit well with the single-mechanism and especially connectionist models.

The authors also concede that it is possible to account for these findings in line with the revised dual-route model which would distinguish between a process of assembly/disassembly of a form and mapping of the input onto whole-word representations. This model developed by Marslen-Wilson and Tyler (1997, 1998) as well as Post et al. (2008) focuses on the compositional properties of the words rather than their regularity *per se.* Under this view, findings from French and English could be reconciled, as irregular verbs in English such as *sprang* cannot be decomposed into smaller units whereas in French all forms consist of a stem and at least one affix. Hence, morphological parsing is claimed to be obligatory in French. The stem allomorphy is not expected to reduce facilitation effects as allomorphic forms also enter into the concatenative paradigm with attached inflectional affixes.

A recent study in French by Estivalet and Meunier (2016) reported a full priming effect for the 1st class fully regular -er verbs, the 3rd class regular verbs in -ir and only a partial priming for the verbs with allomorphic alternations from the 3rd class in both cross-modal and masked priming experiments. A full priming effect was interpreted as evidence of decomposition down to the root, since there were different stems in primes and targets. The partial priming effect for other verbs might indicate linked stem representations or allomorphic rules similarly to the assumptions made by Stockall and Marantz (2006).

Similarly to the findings by Meunier and Marslen-Wilson (2004) Orsolini and Marslen-Wilson (1997) found a similar amount of priming in a cross-modal priming study of Italian when primes and targets belong to the default 1st conjugational class (e.g., *amarono* ‘they loved’ – *amare*) and to the 2nd conjugational class with stem alternations (*presero* ‘they took’ – *prendere*) which is considered to be irregular. According to Say and Clahsen (2002) this study is not without its share of drawbacks as, for example, it has not included an identity condition which could have allowed to detect differences between classes as a contrast between the full and partial priming effects. Furthermore, verbs of the 1st and 3rd conjugations were collapsed and treated as regular whereas only the 1st class appears to be the default one and hence rule-based. Experimental evidence also indicates potential differences in processing mechanisms, as patients with Alzheimer’s disease appear to be more impaired in producing irregular (2nd class) verb forms in the-present tense and past-participles forms compared to the spared production of the 1st class verbs, even though the effect size is relatively small (Walenski, Sosta, Cappa, & Ullman, 2009).

Using ERP violation paradigm to investigate processing of participles in Catalan, it was found that LAN effects arise only in cases of overapplication of the -a- theme vowel typical of the default 1st conjugation to the verbs requiring a 2nd or 3rd conjugation (as in **dorm-a-t* instead of *dorm-i-t*) form but not vice versa (e.g., **cant-i-t* instead of *cant-a-t*) (Rodriguez-Fornells, Clahsen, Lleó, Zaake, & Münte, 2001). The authors assume that LAN effects are due to violation of morphological decomposition resulting from incorrect application of -a stem formation rule to the verb which should block such a rule. Absence of negativity effects in case of the incorrect 1st conjugation forms is arguably due to the absence of -i stem formation rule and storage of the 3rd conjugation stems.

The ERP repetition priming study on Spanish included targets belonging to the 1st conjugational class which is a default one and targets belonging to other classes (Rodriguez-Fornells et al., 2002). Crucially, whereas there is no stem alternation in the 1P.Sg.Pr. primes in 1st class verbs (e.g., *estudio* ‘I study’ - *estudiar*), vowel alternations are common in such forms in other classes (e.g., *entiendo* ‘I understand’ - *entender*). The N400 effects were reported only for forms with no alternations. These findings were attributed to the differences in processing mechanisms such that only regular forms are decomposed, whereas verbs with an altered stem/root have a subentry for such stems/roots (*entiend*-). The reaction time data, however, revealed similar priming effects for both groups of verbs. The authors assumed that "RT reflects the final outcome of the entire information processing sequence under study, while the N400 component indexes some intermediate stage of analysis" (Rodriguez-Fornells et al., 2002, p. 449).

A cross-modal priming study on Portuguese included forms from the default 1st conjugation and from the 3rd conjugation as visually presented targets preceded by the auditory primes (e.g., *limitar – limito* 'I limit' and *adquirir – adquiro* 'I buy') (Veríssimo & Clahsen, 2009). Whereas verbs from the 1st class led to the full priming effect, verbs from the 3rd produced only partial priming effect. According to the authors, the root which was directly activated by the prime and the target is the main entry of the verbs from the 1st conjugation. In contrast the lexical entry of the verbs belonging to the 3rd conjugation contains two entries, that is a stem such as *adquiri* and a root *adquir,* and hence the activation from the stem-based prime is indirect and reduced. The experiment also showed that verbs with stem changes such as *af[u]gar – af[ɔ]go* 'I drown' from the 1st class lead to the partial priming effect similarly to the verbs from the 3rd class. Veríssimo and Clahsen (2009) assumed that lexical entries of such verbs include a second alternated root.

To summarize, the discussed studies on processing of complex inflected forms indicate that the distinction between regular and irregular inflected forms originally observed in English past tense forms and latter applied to other languages is too simplistic. The application of this approach to Romance languages with several conjugational classes might obfuscate the differences between inflectional processes and properties of stem-formation morphology (Clahsen, 2016). In all examined studies on Romance languages inflectional endings are regular and do not differ across conjugations. Based on experimental findings researchers appear to mostly agree that initial stages of word recognition involve decomposition of such complex forms into stems and inflectional endings. No morphologically complex form with an inflectional affix is assumed to be stored as a frozen entry.

It seems, however, more difficult to determine how the stems are represented and what factors influence their further processing. There is little doubt however that stems of default classes without any allomorphic changes (usually the 1st conjugation class in Romance language) are fully combinatorial structures which in priming studies leads to the decomposition of the stem to the root and hence to a full priming effect due to the direct activation of the root. If stems show allomorphic changes which often characterize non-default conjugational classes (but not only: see *af[u]gar –*

af[ɔ]go 'I drown' in Portuguese), they appear to be processed differently as often indicated by experimental data such as reduced facilitation effects in priming studies or lack of N400 effects. This general pattern could be explained if such stems are posited to "comprise sets of items stored in the mental lexicon" (Clahsen, 2016, p. 607) instead of being outputs of a morphological rule. This view is more compatible with the assumptions of the dual-route model interpreted as postulating a universal opposition between linguistic units that are stored and those that are computed by rule-based operations rather than between regular and irregular forms.

While single-mechanism full-decomposition models could also account for the initial segmentation of the inflected forms into stem and inflectional ending, usually observed processing differences between two stem types can be hardly explained. If stem allomorphy is argued to be rule-based as well, processing of such stems should not be any different from computational processing of default stems without stem changes contrary. As mentioned earlier, this is not usually the case and studies supporting similar views like those presented by Orsolini and Marslen-Wilson (1997) on Italian often have serious flaws. Full-storage models or models assuming only late activation of morphological constituents appear to be incompatible with existing findings from priming studies indicating rapid decomposition into morphemes as well as existing differences in processing of various stem types. As the morphologically complex words in such models are assumed to be accessed as wholes, it is unclear why this mechanism should lead to any processing differences for various inflected forms.

On the whole, experimental data obtained for inflected words is more compatible with an approach proposing a contrast between stored unanalyzed linguistic units and those that are computed by rule-based operations. However, the question remains to what extent the observed findings and assumptions are universal. The priming experiments by Reid and Marslen-Wilson (2002) on Polish and by Gor and Jackson (2013) on Russian have not found any effects of the stem allomorphy on morphological processing. Is it due to the absence of the identity condition in these studies or do these findings indicate that the single-mechanism decomposition-based approach could better account for processing of inflected forms in Slavic languages? Furthemore, the studies discussed above have often relied on experimental methods tapping into more central levels of morphological processing. So another question is whether at the initial stage of word recognition, class membership and stem alternations would also play a role in word processing at the level of access representations. These issues will be addressed in the present study.

1.3 Processing of Derivational Morphology

Whereas inflection could be seen as a grammatical process that spells out morphosyntactic features and adds no additional semantic information, derivation is a word-formation process that produces new lexical entries (i.e., words with novel grammatical and/or semantic characteristics) according to realization-based accounts of morphology (Anderson, 1992). The aim of psycholinguistic research as argued by Havas, Rodríguez-Fornells, and Clahsen (2012) is to establish whether derived words shows properties of combinatorial word forms or stored lexical entries. These properties of the derived words should be reflected in experimental findings.

If a derived lexeme is stored holistically in the mental lexicon, it would imply that the frequency of its surface form rather than of its base should modulate response latencies during recognition process. Unprimed lexical decision experiments which manipulate the frequency of the presented words were considered to test precisely this assumption. Clahsen et al. (2003) performed a lexical decision task having included German nouns with nominalization and diminutive affixes (*-ung* and *-chen*, accordingly) which differed in surface frequency while controlling for the base word frequency. As hypothesized, high-frequency nouns elicited shorter reaction times and thus were recognized faster than nouns of lower frequency. The authors assumed that these findings indicate availability of full-form representations for the derived nouns. The same finding for the –ung affix was also reported in yet another study (Clahsen & Neubauer, 2010). Similar full-form frequency effects were also found in studies on other languages, for example, Finnish (Vannest, Bertram, Järvikivi, & Niemi, 2002).

There are, however, some doubts regarding the interpretation of surface frequency effects as indicating a whole-word retrieval. For example, even though Taft (2004) admits that when it comes to derived words which are often not semantically transparent (e.g., *feathery* in English) whole-word representation should still exist is the system, it is possible that decomposition of such words still takes places. The surface frequency effects, that is faster response times to items having higher surface frequency compared to items with lower surface frequency, could allegedly reflect processing costs which arise after the initial segmentation into a stem and an affix.

Taft (2004) refers to a later “postdecomposition recombination stage” when morphemes are combined and examines inflected forms such as *growing* and *seeming*. It is claimed that forms differ with regard to “the ease with which the information associated with the stem (*seem* vs. *grow*) can be combined with the information associated with the affix (*-ing*)” (Taft, 2004, p. 747) as *seem* is a static verb. Though the details concerning derivation are not discussed, it could be also possible to assume a similar explanation for derived words, considering multiple semantic constraints on formation and interpretation of, for example, -ung nouns in German as discussed in Chapter 3.1.1.1. However, even if one takes into account the abovementioned account of the surface frequency effects, it does not deny the existence of full-form representations for the derived nouns.

The masked priming method used in a variety of experiments may arguably lead to completely opposite conclusions relative to those based on simple lexical decision tasks as the majority of the studies find evidence of the morphologically blind affix stripping mechanism. These studies show that when a prime is morphologically complex (e.g., *reader*) or only appears to be morphologically complex (e.g., *corner*), it still facilitates recognition of a target word (Rastle et al., 2004).

The found facilitation effect is morphological in nature and cannot be attributed to the mere semantic and orthographic overlap, because words such as *broth* were effective primes of *brother* but not *brothel* in English. Even though both target words are morphologically simple, the word *brother* appears to have a similar structure to complex words with a *–er* affix (e.g., *teacher*) existing in English, whereas there is no *-el* affix in English and thus *-el* is not automatically stripped off. These findings point to the pure morpho-orthographic segmentation during very early stages of processing (Rastle & Davis, 2008).

In a masked priming experiment on English Silva and Clahsen (2008) reported a full priming effect for morphologically complex deadjectival nominalizations in English with *–ity* and *–ness* affixes which differed in the degree of their orthographic overlap. Nevertheless, the authors found an equally significant priming effect for both groups of derived words.

Priming effects for derived words were found in cross-modal priming experiments as well. For example, the experiment by Sonnenstuhl et al. (1999) examining processing of derived diminutive nouns in German showed a full priming effect indicating full decomposition of the morphologically complex prime. The study included two groups of nouns, namely with and without regular vowel change in the derived form (e.g., *Dach* 'roof' – *Dächlein* and *Licht* 'light' – *Lichtchen*, respectively). A completely predictable vowel change did not affect the magnitude of the priming effect.

Experiments with overt presentation of primes indicate that further stages of word recognition are sensitive to semantics. Marslen-Wilson, Tyler, Waksler, and Older (1994) showed that semantically opaque pairs (e.g., *apartment - apart*) do not yield a facilitation effect in contrast to semantically transparent pairs (e.g., *punishment - punish*). Evidence from other studies confirms that semantic factors play an important role during the recognition of derived words (Rastle, Davis, Marslen-Wilson, & Tyler, 2000). Thus, while the morphological processing at earlier stages appears to be largely automatic and not affected by semantic factors, it is more semantically informed during later stages of processing. One way to account for differences between processing mechanisms would be to assume that the second one reflects, for instance, a "licensing'' procedure which deletes incorrect pseudo-affixed decompositions based on semantics (Meunier & Longtin, 2007).

Note, that the studies mentioned above discuss facilitation effects in terms of morphological parsing and morphemes as core processing units. However, there are also alternative approaches in line with connectionist models as represented by Gonnerman, Seidenberg, and Anderson (2007). The priming effect is assumed to be due to orthographic and semantic overlap between derived and underived words. Moreover, simultaneous semantic and orthographic overlap typical of morphologically related words may yield a greater facilitation effect compared only to semantic or only to orthographic overlap. Although this account may indeed provide explanation for findings from the overt priming experiments, it is not immediately clear how it can account for similar priming effects for affixed and pseudo-affixed words in the masked priming experiments as noted by Crepaldi et al. (2010). A similar problem arises for other single-mechanism accounts and specifically for the full-storage models and supralexical accounts of morphological processing as words such as *corner* should not be decomposed into *corn* + *er* at all in contrast to existing words such as *hunter* (Taft, 2015).

On the whole, the discussed priming effects found for derived words are more in line with the modified version of the dual-route model as suggested by Clahsen et al. (2003) which takes into account the dual nature of the derived words. Derived words are stored in the mental lexicon preserving their morphological structure (Clahsen et al., 2003). While the unprimed lexical decision experiments usually interpreted the surface frequency effects as being typical of stored lexical entries, priming effects indicate that those entries are morphologically structured and could be represented as, for example, *[Reinig]*$_V$*-ung]*$_N$ in the case of -ung nominalization in German. Priming effects of such words may then arise through morphological decomposition and affix stripping followed by a stem reactivation for regular forms. Alternatively, it may be lexically-mediated and arise at the lexeme level. Lexeme of the derived word such as *[bitter]-ness]*$_N$ is partially shared with the lexeme of the base word *[bitter]*$_{Adj}$ leading to a priming via the lexical route similarly to *fell-fall* effect (Kırkıcı & Clahsen, 2013). As mentioned earlier, the properties of this model allows researchers to better account for both surface frequency effects of derived words as well as for facilitation effects in priming studies showing availability of the morphological constituents compared to single-mechanism models. This model, however, has never specifically addressed processing mechanisms of pseudo-derived words such as *corner*. One may assume though that they could be processed by the affix stripping mechanism as the second route is clearly unavailable in these cases.

The findings and models concerning the processing of the morphologically complex inflected and derived words reported in this chapter and the previous one are usually based on studies testing healthy young participants. However, processing mechanisms could differ across various groups of speakers as revealed by studies focusing on populations potentially more challenged with regard to language processing such as language learners.

This dissertation investigates another group which might also struggle with some aspects of language processing in general and morphological processing, specifically older adults. In order to understand why older adults might be more challenged in this respect I will review in the following chapter the existing literature on age-related cognitive changes and complex patterns of cognitive decline and maintenance observed with advancing age. Next the potential effects of cognitive ageing on morphological processing will be reviewed based on available experimental evidence.

1.4 Cognitive Ageing and Language Processing

Increased age is often associated with a decline in cognitive abilities and poorer performance in cognitive tests. However, whereas advancing age is usually associated mostly with losses, it is an oversimplification of a more complex picture. Some abilities such as memory and processing speed tend to decline, whereas others such as one's vocabulary are mostly maintained (Harada, Natelson Love, & Triebel, 2013) or even improve as a result of one's lifelong exposure. Researchers include vocabulary richness, collocational knowledge and even articulatory fluency into the last group (Baayen, Tomascheka, Gahlc, Ramscar, & Baayen, 2015; Ramscar, Hendrix, Shaoul, Milin, & Baayen, 2014).

Park (2000) identifies four fundamental properties and factors, which might be responsible for a substantial decline in cognitive domains: the speed of processing, the working memory function, inhibitory function and sensory function.

Salthouse (1996) assumed that variance in performance between older and younger adults could be accounted for by decreased speed of mental operations. older adults arguably perform worse in complex cognitive tasks because they are slower to perform required earlier operations and may not reach the later stages in available time. Thus, performance of older adults may become worse even on tasks which may seem to lack a speed component such as those involving working memory, reasoning and verbal fluency.

Another mechanism is based on the assumption that older adults possess fewer processing resources which could negatively affect the number of memory operations and their quality (Park & Festini, 2017). This approach has been often applied to the working memory. In contrast to short-term memory working memory requires not only the maintenance, but active manipulation and transformation of information (Drag & Bieliauskas, 2010). This additional processing may increase demands on cognitive resources and explain the greater age-related decline of working memory compared to short-term memory.

The inhibition deficit hypothesis focused on compromised inhibitory processing in cognition in older age (Hasher & Zacks, 1988). Ageing presumably limits one's ability to focus on the relevant aspects as well as not getting distracted by irrelevant information. The observed differences between older and younger adults arise due to the maintenance of irrelevant information in the working memory. The role of inhibition remains controversial due to the methodological limitations as a reliable measure of inhibitory functions has not been developed (Park, 2000).

Poorer performance of older adults could be also mediated by sensory / perceptual deficit. As a result older adults process incomplete or erroneous signals. The importance of this mechanism has been first highlighted by Lindenberger and Baltes (1994), who have shown that age-related variance in 14 tests of cognitive abilities is explained by sensory functioning. Thus, it may be an indicator of neuronal integrity of the brain.

The factors mentioned above could account for some differences in language comprehension and production between younger and older adults as summarized by Burke and Shafto (2008). General slowing might be responsible for the difficulties of older adults to comprehend speeded speech or their inability to make use of sentential context to disambiguate homophones. Furthermore, slowing could have a negative impact on the dynamics of priming such as the speed of the transmission of activation to related representations. As a result, less information necessary for activation and therefore subsequent retrieval of an item would be available (Dell, Chang, & Griffin, 1999).

Reduced working memory capacity was employed to account for variability in processing of complex syntactic structures. The difficulty in comprehension of and preference for production of left-branching compared to right-branching sentences may be due to higher working memory demands of the former type of sentences (Kemper & Kemtes, 2002). Less efficient inhibition could potentially explain the tip-of-the-tongue experiences. The tip-of-the-tongue experiences (TOT) phenomena could be also explained by a transmission deficit hypothesis which assumes that connections between phonological and semantic representations could become too weak to transmit enough excitation for phonological representation to reach a necessary threshold for production.

Theories which attempt to account for various ageing-related phenomena based on a single mechanism are often criticized for being too general and broad (Thornton & Light, 2006). Instead a more multifaceted approach appears to be more promising (Park & Festini, 2017). Whereas previously working memory, inhibition and attentional capacity were examined as being independent of one another even though they may be different aspects of a single construct, namely executive functioning (Salthouse, Atkinson, & Berish, 2003). Its goal is to override automatic behavior, by allowing to "attend selectively, to concentrate on a particular task, to make choices in line with current goals, and to facilitate new learning" (Craik & Bialystok, 2006, p. 134). Hence, the pattern of cognitive age-related changes could be understood as a decline of control processes which leads to difficulties in access to already existing knowledge.

When discussing effects of ageing on memory, it is important to keep in mind, that there are several components which could be differentially affected. The broadest distinction is between declarative and nondeclarative memory. Whereas declarative (explicit) memory is responsible for conscious retrieval of facts, experiences and events, nondeclarative (implicit) memory is outside of one's awareness and involves unconscious access to information (Birren, Schaie, Abeles, Gatz, & Salthouse, 2006; Harada et al., 2013). An example of nondeclarative memory is procedural memory which is memory of motor and cognitive skills and is involved in various tasks including processing of rules, sequences and repetition priming etc. (Birren et al., 2006; Ullman, 2016). This type of memory is considered to be either completely unaffected by ageing or show only mild negative effects (Birren et al., 2006; Harada et al., 2013).

Declarative memory and some of its subsystems show more severe age-related changes. Problems with word-finding may suggest deficits in semantic memory which is viewed as being responsible for storage of factual knowledge including definitions of the words, real-world facts (Harada et al., 2013). However, there are alternative explanations which point to access difficulties (Drag & Bieliauskas, 2010). Furthermore, semantic memory may actually increase with advancing age due to accumulated experience. Indeed, measures of semantic memory (e.g., vocabulary size) were shown to even increase until about 55 (Hoyer, Verhaeghen, & Birren, 2006; Rönnlund, Nyberg, Bäckman, & Nilsson, 2005).

On the whole, whereas it appears that no single factor is capable to fully account for all ageing phenomena, speed of processing is responsible for the majority of differences in tasks when examining cognitive abilities (Park & Festini, 2017). Language abilities are also affected as older adults experience word-finding difficulties, show decline in syntactic complexity measure etc. Some of the cognitive domains affected by ageing including declarative memory are responsible for processing of morphologically complex words. For instance, idiosyncratic language knowledge processed by declarative memory is related to semantic memory as noted by Ullman (2016). Furthermore, ageing could impact access to and the retrieval of information. Access difficulties could affect processing of idiosyncratic forms as comprehension of such a form involves its successful retrieval from the memory and establishing a link to the stem.

Whereas the potential effect of ageing has been assessed in syntax processing, production of orthography and speech recognition, processing of morphologically complex words has received much less attention. Relevant studies will be reviewed in the next chapter.

1.5 Ageing and Morphological Processing

To date, only few studies have investigated effects of ageing on morphological processing. I will start with experiments which found similarities between older and younger participants. Then I will present studies which found age-related differences in morphological processing and discuss whether and how it is possible to reconcile opposing findings.

The first experiment by Kavé and Levy (2004) tested the ability to decompose words by examining healthy old native speakers of Hebrew and Alzheimer's disease (AD) patients using two types of pseudoword stimuli. They have included pseudowords which contained existing three-consonant roots in Hebrew inserted into six morphological patterns, yielding nonexisting verbs in Hebrew. The other type of pseudowords contained nonexisting three-consonant roots inserted into the same patterns. Kavé and Levy (2004) found differences in processing two types of nonce-stimuli showing sensitivity of both groups to morphological structure as it took longer to reject stimuli with existing three-consonant roots in Hebrew which closely resembled existing words in Hebrew than pseudowords with nonexistent morphemes.

With regard to existing words Kavé and Levy (2004) investigated morphological processing mechanisms using a cross-modal priming paradigm. The experiment included four types of prime-targets pairs: morphologically related, unrelated, phonologically as well as both morphologically and semantically related. It was found that both groups of participants reacted faster to targets following morphologically and both morphologically and semantically related primes than control primes. The authors conclude that both groups show preserved ability to decompose morphologically complex words.

However, the morphological properties of Hebrew are very dissimilar from those in Indo-European languages due to its non-concatenative morphology which similarly to other Semitic languages involves non-linear combination of consonantal roots and vowel patterns (e.g., *L-M-D* + taCCiC = *talmid* ‘pupil’). Due to this property, the lexical processor in Hebrew was assumed to be ‘more’ morphological than in Indo-European languages where it is additionally influenced by other nonmorphological factors such as orthographic surface form and semantic transparency (Bick, Goelman, & Frost, 2011; Frost, Deutsch, Gilboa, Tannenbaum, & Marslen-Wilson, 2000) and could therefore be potentially less vulnerable to negative effects of ageing.

Duñabeitia, Marin, Aviles, Perea, and Carreiras (2009) examined the processing of morphologically complex words in Spanish by testing the decomposition of transparent compounds in healthy old adults. They have selected compounds (e.g., *pasatiempo* ‘pastime’) preceded either by the first constituent lexeme (e.g., *pasa* - *pasatiempo*), or by the second constituent lexeme (e.g., *tiempo* - *pasatiempo*), or by the unrelated word. The priming patterns revealed that older adults produce a reliable constituent priming effect independent of the lexeme position. The authors also found evidence in favor of the general slowing hypothesis due to the increase in response latencies in older adults.

In contrast to the two studies presented above other studies found some age-related differences with regard to morphological processing. For instance, the study by Clahsen and Reifegerste (2017) which also used a cross-modal priming paradigm examined the processing of regular -t participles (e.g., *gefragt* “asked” – *frag)* and irregular -n participles (e.g., *geschlafen* “slept” – *schlaf)* by old native speakers of German and compared the data to the findings from younger speakers reported by Clahsen and Fleischhauer (2014). The findings by Clahsen and Reifegerste (2017) indicate a selective effect of ageing on processing of irregular inflected forms. Regular -t participles yielded robust priming effects in both age groups, while priming effects for -n participles were not any more extant in the group of older adults. The authors hypothesized that recognition of the irregular form requires memory access which becomes less efficient such that “the link between the entry for an -*n* participle form and its corresponding stem entry has become too weak to be immediately co-activated” (Clahsen & Reifegerste, 2017, p. 230).

This claim was supported by findings from the experiment on participle production conducted by Clahsen and Reifegerste (2017). The participles included into the experiment varied with regard to their word-form frequency. Frequency advantage (i.e., shorter reaction times to words with higher surface word-form frequency) was observed only for highly irregular -n participles with a vowel change. Crucially, this advantage was observed not for all participants but only for those who scored in a CERAD (i.e., a battery of cognitive tests which could be viewed as a proxy of verbal memory) at least 85 out of 100. Moreover, its magnitude increased the higher one's score was. It was assumed that "the benefits for processing a lexically-primed or a high-frequency word form are reduced at old age" (Clahsen & Reifegerste, 2017, p. 238) due to the weaker associative links between entries in the memory and lower activation levels as a result of the decline of lexical memory.

Two other studies using a simple lexical decision task also found differences between older and younger adults. For instance, Reifegerste (2014) in the doctoral dissertation examined processing of regular and irregular inflected verb forms by older adults in Dutch. It was hypothesized that if an inflected form is stored, word form frequency effects should arise, whereas if it is computed online, stem-frequency effect should be more pronounced. In contrast to younger adults Reifegerste (2014) found an overall advantage for words of high frequency and no interaction between form frequency and regularity in the group of older adults. Thus, it has been assumed that older people access irregular as well as regular forms as whole words. This effect has been ascribed to the amount of previous exposure and concomitant changes in the structure of the mental lexicon. Regular forms which were not of sufficient frequency for younger people to be identified by a direct whole-word retrieval route presumably gain enough frequency and could be easier recognized holistically by older adults.

A recent study by Reifegerste, Meyer, and Zwitserlood (2017) examined the processing of plural nouns by young and old speakers of Dutch and German to investigate the role of morphological richness of a language. The two groups of German native speakers differed with regard to the effect of number dominance in a simple lexical decision experiment. For younger speakers the response latencies were longer to the plural than to the singular forms regardless of number dominance, whereas for older people an effect of dominance for plural nouns only has been found. Reifegerste et al. (2017) concluded that response patterns for younger adults signal decomposition of plural nouns, whereas older adults rely more on a storage-based mechanism during comprehension of plural-dominant plural forms.

The data from the two Dutch groups are similar to the mentioned findings for the group of older adults in German. To explain the difference in response patterns between young German and

Dutch native speakers Reifegerste et al. (2017) refer to the morphological richness of German. Extra 40 years of experience of German adults with complex inflected forms supposedly facilitate a whole-word access reaching the balance between storage and decomposition as observed in a less morphologically rich language such as Dutch.

As the results from all discussed studies indicate there appears to be a contrast between experiments finding effects of ageing on morphological processing and those which report similarities between older and younger adults. The question is whether the findings from various studies could perhaps still be reconciled. The studies on Hebrew and Spanish focused on the processing of morphologically complex words which are claimed to involve combinatorial operations. The results from these studies indicate that mechanisms involved in recognition of such complex words remain intact during healthy ageing. As a matter of fact, another priming study by Clahsen and Reifegerste (2017) also shows similar priming effects for older and younger adults with regard to processing of regularly inflected German -t participles which are also assumed to be rule-based and combinatorial.

The priming study by Clahsen and Reifegerste (2017) also focuses on morphologically complex words which are, however, assumed to be lexically-stored and specifically stored on irregular past participles. The results indicate that the processing of irregular items, which relies more on the lexical memory, seems to be more affected by ageing probably due to the age-related memory decline and weaker links between irregular forms and their corresponding stem entries. Thus, the study by Clahsen and Reifegerste (2017) does not contradict findings from Hebrew and Spanish but rather refines them.

Studies using a different experimental paradigm and specifically simple lexical decision tasks arguably show greater reliance on storage with advancing age even in case of decomposable forms such as regular Dutch verbs as reported by Reifegerste (2014). However, with regard to this particular study several factors should be taken into consideration. Frequency-based effects from the unprimed lexical decision experiments were questioned as being a suitable tool to examine decomposition-based processing of morphologically complex forms (Marslen-Wilson, 2007). It is possible to interpret surface frequency effects in the case of regular forms as being associated with the "frequency of the computation of the combination of morphemes, not the frequency of the static whole forms themselves" (Marantz, 2016, p. 162). Under this view the longer experience of older adults with certain forms compared to younger adults may possibly increase the efficiency and automaticity of this process with age. This explanation could account, for instance, for findings on

Dutch verbs reported by Reifegerste (2014). On the whole the majority of studies still shows similarities rather than differences between older and younger adults concerning processing of combinatorial forms.

Another lexical decision study by Reifegerste et al. (2017) is more difficult to integrate with earlier reported findings and should be treated with caution. To begin with, it examines processing of German plural endings all of which, as authors admit, are usually considered to be irregular (see more on German plurals in Chapter 3.2) and finds no surface frequency effects in the group of younger adults. This result apparently contradicts previous findings from other studies which, among others, used the same experimental paradigm as, for instance, Sonnenstuhl and Huth (2002) who observed a robust frequency effect for -n plurals forms and found no such effect only for the presumably default -s plural. The source of this discrepancy remains to be further investigated as apparently -n plurals constituted the majority of tested plural forms in the study by Reifegerste et al. (2017) as well. Nevertheless, the study could be interpreted as showing age-related changes in the domain of processing of irregular forms arguably indicating more reliance on storage-based processing mechanisms with advancing age.

In a nutshell, the studies on effects of ageing on morphological processing could be taken to indicate general maintenance of rule-based operations and combinatorial processing in older age and often reveal age-related differences concerning processing of morphologically complex words which are usually assumed to be lexically-stored. In this domain two competing hypotheses could be pointed out. According to Clahsen and Reifegerste (2017) recognition of irregular forms becomes less efficient due to the decline of lexical memory, whereas alternatively the reliance on a storage-based processing mechanism and its efficiency increase with age as a result of lifelong exposure and experience as argued by Reifegerste et al. (2017).

Currently, it remains unclear how cross-linguistically robust the observed effects are and whether age-related effects mostly found for inflected forms in German would also be confirmed in other languages. Furthermore, another open question is whether age-related effects could be also detected by other experimental methods such as a masked priming paradigm which is sensitive to decomposition-based processing especially during initial and supposedly automatic stages of word recognition as compared to the cross-modal priming and simple lexical decision techniques.

1.6 Overview: The Experimental Studies

In the subsequent chapters of the PhD thesis I will attempt to contribute to the debate concerning the nature of the morphological processing mechanisms by investigating initial stages of word recognition in Russian and German in older adults. The chosen languages will allow me to examine the contrast between whole-word forms often treated as either regular or irregular and stem-formation which could be, for example, combinatorial or allomorphic. Clahsen (2016) notes that two phenomena have been often confused and very few studies have directly examined the properties of stem-formation mechanisms as well as differences between various types of stems and mechanisms of their recognition.

As discussed in Chapter 1.2 Processing of Inflectional Morphology experimental data suggest a general contrast between stored unanalyzed linguistic units and combinatorial units computed by rule-based operations. However, it remains unclear whether this contrast is universal as several experiments, for example, on Slavic languages as by Reid and Marslen-Wilson (2002) on Polish and by Gor and Jackson (2013) on Russian claim to have found no effects of the stem allomorphy on morphological processing. The reported results may be due to the design of the studies (e.g., absence of the identity condition) and/or experimental methods (e.g., overt priming) possibly susceptible to the influence of non-morphological factors (e.g., semantic effects). On this view, one may expect to observe the dichotomy between stored linguistic units and combinatorial units in a study on, for example, Russian which attempts to overcome the mentioned issues. In the next section of the present study Part I. Experimental Study of Processing of Complex Words in Russian I will examine processing of verbal stems with and without allomorphic alternations testing whether the contrast between stored and combinatorial units could be observed in Russian as well. The data would be then compared to regular and irregular inflected forms in German examined in the section Part II. Experimental Study of Processing of Complex Words in German.

While German and Russian make it possible to compare processing of inflected forms which differ with regard to the nature of the linguistic processes, they also allow me to examine the mechanisms of recognition of derived words. As properties of examined derivational phenomena are comparable (e.g., in terms of productivity), one would predict to find similarities across two languages reflecting the nature of the derived word which are claimed to have a structured lexical entry in the mental lexicon (Jacob et al., 2017; Kırkıcı & Clahsen, 2013). These assumptions would be tested in the following chapters of the present thesis.

I will focus on a group of speakers, which is rarely examined in experimental studies on morphological processing, namely older adults. The experimental data concerning processing of the morphologically complex words reported in previous chapters are usually based on young adults. Therefore, the question arises as to what extent the usually reported behavioral data and findings are group-specific. Processing mechanisms could vary across groups of speakers as shown by studies testing special populations such as language learners which may be potentially more challenged with regard to some aspects of morphological processing (Jacob et al., 2017; Kırkıcı & Clahsen, 2013; Neubauer & Clahsen, 2009). As our review of existing literature on cognitive ageing and available studies on language processing has demonstrated, similar claims might be true in case of older adults as well (see below).

While combinatorial processing in older adults appears to be generally preserved, processing of lexically-stored morphologically complex words appears to be more affected by ageing either being due to the decline of lexical memory (Clahsen & Reifegerste, 2017) or, alternatively, reflecting increased efficiency of the full-form access mechanism as a result of lifelong experience with such forms (Reifegerste et al., 2017). If this is indeed the case, one might find specific effects of ageing in processing of stored linguistic units such as irregular forms in German or allomorphic stems in Russian and possibly derived words by older adults compared to the control groups of younger adults. Furthermore, processing of rule-base units such as regular forms or combinatorial stems should not be affected by ageing in our study. Alternatively, effects of ageing could be global rather than specific to a particular processing mechanism reflecting, for instance, the usually observed general slowing of older adults (Salthouse, 1996). These hypotheses will be experimentally investigated in the ensuing chapters.

In the next chapter of the dissertation Part I. Experimental Study of Processing of Complex Words in Russian I will present two masked priming experiments on Russian examining the processing of derived and inflected words. I will begin with the linguistic description of the phenomena followed by the summary of previous experimental findings. Then, I will separately present data from experiments on derivation and inflection comparing processing from the experimental group of older adults to the control group of young adults. This will be followed by the combined analysis comparing observed effects for derived and inflected words and as well as a discussion of the findings.

The chapter on processing in Russian will be followed by the Part II. Experimental Study of Processing of Complex Words in German examining processing of complex words in German. The first part of this chapter will examine the processing of derived and regularly inflected forms by older adults in German. The second part will compare the processing of regular and irregular plural forms in German. These two parts are similarly structured and begin with a review of the phenomena in German followed by the summary of previous findings. These sections will be followed by the presentation of experimental results and their discussion.

Finally, in Chapter 4 General Discussion and Conclusions I will discuss the main findings from the previous experimental chapters on processing of complex words by older adults in Russian and German and will draw some general conclusions in light of the new data.

2 Part I. Experimental Study of Processing of Complex Words in Russian

2.1 Processing of the -ost' Derivation and Verbal Inflection in Russian.

In the following chapters I will review relevant properties of the -ost' derivation and verbal inflectional morphology in Russian. While derivation and inflection could be generally regarded as constituting a continuum between prototypical derivation and prototypical inflection, we will focus on prototypical instances in Russian.

2.1.1 A linguistic description of derivation by means of the -ost' affix in Russian.

One example of derivation in Russian is nominalization of adjectives by means *-ost'* affix which gives rise to abstract nouns (e.g., *staryj* 'old' – *star-ost*' 'old age') (Corbett, 2004).

Traditionally three inflectional noun classes are postulated for Russian. According to Corbett and Fraser (2000) Class III includes feminine nouns that have a -Ø ending in Nom Sg. All stems in Class III end either in a palatalized consonant or the consonants [š] or [ž], which diachronically used to be palatalized. Of 5150 members of the Class III, it is estimated that around 4300 are derived by means of the -ost' affix. Moreover, the -ost' affix is also highly productive in Contemporary Russian. To illustrate this, the following examples can be given: *anonimnyj* 'anonimous' – *anonimnost'* 'anonimity', *sovetskij* 'soviet' – *sovetskost'* 'state of being soviet'.

The most extensive analysis of -ost' nouns until now albeit mostly from the historical perspective, has been presented by Shanskij (1948) who claims that this is the only productive affix in modern Russian to derive abstract nouns denoting a quality defined by the adjective. Bajandina (1999) points out several factors explaining the growth in productivity of the -ost' affix. For example, from the morphological point of view, the -ost' affix could be used with a larger number of base stems compared to, for example, *ot-a, in-a, izn-a.* Additionally, in contrast to, for example, *-in-a* or *-stv-o* it does not have any homonymic affixes. Furthermore, the derived *-ost'* nouns were more stylistically neutral compared to the nouns derived by competing affixes. The following hierarchy of abstractness of affixes in contemporary Russian has been suggested: *-izn-a, in-a, ot-a, ost'* (Janceneckaja, 1979).

Lukicheva-Navros (2005) has analyzed 3619 nouns ending in *-ost'* and its allomorphs *nost', -est'*. The nouns were derived from either derived or underived words. The underived words are represented by adjectives and this pattern included 514 nouns. The most numerous pattern is of the type: "morphologically complex adjective + *-ost'/ est'* " and has 3097 entries (with the most numerous subtype consisting of adjectives derived from nouns (1281 entries)). According to the academic Russian Grammar (Shvedova, 1980) *-est'* is selected if the stems end in sibilants as in *svež-est'* 'freshness'. Considering that none of the affixes of the morphologically complex adjectives derived from nouns end in sibilants, the scarcity of nouns with *-est'* allomorphs becomes explicable.

Apart from *-est',* another variant of the affix is *-nost'* which according to Shvedova (1980) also states that it is *often* selected if the stem ends in sibilants as in *gorač-nost'* 'hot temper'[6]. It should be also noted that Shvedova (1980) treats *-est'* and *-nost'* somewhat differently. Whereas -*nost'* is considered to be an allomorph, *-est'* is listed as an orthographic variety of *-ost'* which is chosen after nouns ending in sibilants. Shvedova (1980) includes an unproductive pattern of deriving nouns from verbs as in *žalost'* 'pity' from *žalet'* 'to pity' and apparently considers *-ost'* affix to be homonymous.

Shvedova (1980) also notes that some nouns have more concrete meaning in modern Russian sometimes even in absence of abstract meanings. Such nouns may be of several types and refer, for example, to collective notions as *živnost* 'livestock' and to individuals as *ličnost'* 'person'. The more concrete meaning could be often indicated by existence of plural forms (e.g., *gluposti* 'stupidity.Pl', *prjanosti* 'spices') (Janceneckaja, 1979). These nouns, nevertheless, represent a minor type compared to the vast majority of -ost' derivations conveying abstract meanings.

According to Shvedova (1980) there are no stem changes in the vast majority of nouns with several exceptions. There is an alternation of plain and palatalized consonants *-n* and *-n'* as in *drevn'ij* 'antique' – *drevnost'* 'antiquity' and 6 more nouns. Furthermore, final stem consonants of adjectives ending with *-ol, -n* and *-k* (after a consonant) are not retained (e.g., *skudnyj* 'scanty' – *skudost'* 'scantiness') in about 10 nouns. Shvedova (1980) notes that *-ost'* nouns derived from adjectives which have a fixed stress on the stem, are also stressed on the same syllable, otherwise the stress falls on the syllable preceding the *-ost'* suffix.

In sum, *-ost'* nominalization is extremely productive in Russian deriving nouns with abstract meanings from either morphologically simple or complex adjectives, though some of these

[6] This should not be mixed with numerous cases when -*n* is part of the stem (e.g. *obš'iteln-ost'* 'sociability' from *obš'iteln-yj* 'social, communicative'). In these cases *-n* is not necessarily part of the root but may be part of the affix, e.g. -*iteln*.

nouns may eventually develop more concrete meanings. Homonymous affixes used, for example, to derive nouns from verbs are unproductive. The application of the *-ost'* affix does not usually lead to stem changes or unpredictable stress shifts with very few exceptions (e.g., *skud**n**yj* 'scanty' – *skudost'* 'scantiness' or *molodOj* 'young' – *mOlodost'* 'youth').

As our study also investigates processing of inflected forms in Russian, we provide an overview of the extremely rich and complicated Russian verbal system in the next chapter of the thesis.

2.1.2 A linguistic description of the verbal inflectional classes in Russian.

In this chapter I will present key approaches to the description of the numerous verbal classes in Russian. One of the main approaches is based on the identification of two stems, that is of the infinitive and the present tense and correlation between them. This approach also takes into account the distinction between productive and unproductive classes and is represented by Zaliznjak (1977) and the Academic Russian Grammar (Shvedova, 1980). The infinitive stem is used in past tense forms and past participles whereas the present tense stem is selected for present tense forms, the imperative and present participles (Timberlake, 2004). The difference between two stems consists in the form of the conjugational affix. It may be longer in one stem and shorter or totally absent in another depending on the class (cf. *igr**at**'* 'to play' – *igr**aj**u* 'play 1P.Sg.Pr.' and *pis**at**'* 'to write' – *pišu* 'write 1P.Sg.Pr.').

The principles outlined above still lead to controversy especially with regard to unproductive classes as Zaliznjak (1977) includes 16 classes, while Shvedova (1980) posits 10 classes which include 19 subclasses. For instance, the I Class according to Shvedova (1980) is defined based on the alternation */zero consonant - j/* and has 5 subclasses including the productive */a-aj/* as in *igra-t'* 'to play' – *igraj-ut* 'play 3P.Pl. Pr.'. One should also consider that in addition to the differences between classes the Russian verb system is posited to have two conjugation types defined by the "thematic ligature used between the stem and the markers of person and number in the 'middle' forms of the paradigm" (Timberlake, 2004, p. 99). For instance, two verb stem types belonging to the I class */a-aj/* and to the X class */a - 0/* belong to two different conjugations. The thematic ligature of the former one is /e/[7] as in *igraj-et* "play 3P.Sg.Pr." from *igra-t'*, whereas it is */i/* as in *vorč-it* "grumble 3P.Sg.Pr." from *vorča-t'.* Two types of conjugations have different endings in 3P. Pl.

[7] or when stressed */o/*

The alternative approach has been proposed by Jakobson (1948) and developed by Townsend (1975). The crucial point in this approach is the treatment of two stems as predictable variants. Jakobson (1948) has shown that it would require only one stem and a set of morphophonemic rules for the majority of verbs to predict the whole paradigm. This stem is defined as a 'basic stem' in contrast to a surface realization which may lack a final stem phoneme and represent a 'truncated stem'. The relation between two stems depends on the type of suffix. Nesset (2004, p. 57) summed up these generalizations using the forms of the verb *delat'* 'to do' and *pisat'* 'to write'

A. "Before a V-initial suffix, the stem ends in a C (cf. /dʲelaj+ot/ and/pʲiʂ+ot/).
B. Before a C-initial suffix, the stem ends in a V (cf. /dʲela+l/ and /pʲisa+l/)".

Furthermore, the second generalization refers to the type of truncation as summed up by Nesset (2004, p. 58):

A. "V → Ø / _ + V ("Delete stem-final V before V-initial suffix"
B. C → Ø / _ + C ("Delete stem-final C before C-initial suffix")"

Owing to these reasons, *-j* would be deleted from, for example, *-aj* verbs followed by consonant-initial affixes in past tense forms. Thus, in theory it is possible to predict all forms of verbs if the basic stem is known.

The typical structure of the verb is described as follows: prefix(es), root, verbal classifier and inflectional ending, as, for example, in *ras-skaz-a-t'* 'to tell' (M. I. Levin, 1995). The 10 classes are determined by the suffix (verbal classifier). These are -aj-, -ej-, -a-, -o-, -avaj-, -ova-, -nu- (including the "disappearing –nu-") all belonging to the 1st -e conjugation and -i-, -e-, -zha- (where the consonant "zh" represents any palatal consonant) belonging to the 2nd -i conjugation. The 11th class has a zero suffix and includes less than 100 basic stems. Additionally, there are up to 20 anomalous stems which show unpredictable behavior in their conjugation.

The difference between two approaches concerns mainly the relationship between two stems, that is whether it is possible to predict the surface form of the stem in a given phonological context. The present study relies on the classification proposed by the one-stem approach following other experimental studies on Russian preferring this classification due to its transparency, that is absence of numerous subclasses (Gor, 2003; Magomedova & Slioussar, 2015; Slioussar et al., 2014).

The number of items per class varies significantly. Slioussar et al. (2014) provide following values for the five productive classes based on the numbers provided in The Grammatical Dictionary of the Russian Language by Zaliznyak (1977) which includes about 27000 verbs: 11,735 in the -aj, 6875 in the -i, 2815 in the -ova, 1377 in the -nu and 638 in the -ej classes. The difference in the degree of productivity could be due to the semantic reasons and functions of the affixes (Feinberg, 1996). The -aj affix is used to derive imperfectives from perfective stems. Other suffixes with -j have some limitations. For instance, -nu derives semelfactive verbs from other verbs, -ova produces verbs from loanwords or technical terms. Similar limitations apply to -i class which usually produces transitive verbs whose function is to "subject the direct object of the verb to the content of the root" (Feinberg, 1996, p. 149). Recent examples such as *skanit'* 'scan' or *guglit'* 'to google' do not violate this assumption. Thus, only -aj is less restricted in terms of its functions as well as semantic properties.

In addition to automatic truncation, several verb classes also have consonantal alternations. This refers to -i and -e verbs in 1P.Sg. and -a verbs before all vocalic endings. These mutations apply only to dental, velar and labial consonants. Whereas in case of dental and velar consonants the alternations are mutations of consonants (e.g., d → ž, t → č, z → ž, s →š, g → k etc.), the changes involving labial consonants also involve an epenthetic *l* (e.g., b → bl', m → ml' etc.). Thus, the stem allomorphy is predictable based on the nature of consonant and verbal class.

There have been several attempts to explain the principles of the Russian verb system. These approaches rely on the notion of markedness. Feinberg (1996, p. 144) suggests that verb stems in Russian are characterized by a "tendency, motivated by the … opposition… corresponding to high vs. low acoustic energy or sonority". The main opposition is between the verb stems with a suffix and the stems which are identical to the root. Each of these types has some "pure" and intermediate types. The -i stems represent the intermediate type whereas the -aj affix is considered to be the perfect example of extension and sonority as it is composed of a low vowel and a glide (Feinberg, 1996). The optimality of its structure accounts for lack of stem alternations. Other extensive suffixes are less optimal, which is reflected in weakened thematicity, that is stem alternations.

The problem of the stem alternations has been addressed by Magomedova and Slioussar (2015) who developed an account in line with the autosegmental theory of mutations by Wolf (2005). This theory holds that affixes may contain floating features. Magomedova and Slioussar (2015) assumed that affixes triggering a mutation, that is *-u* affix in 1 P.Sg. Pr.t. for -i verbs, have a palatal floating feature on the left side which should either be realized as a separate full palatal segment or docks onto the stems final consonant. This accounts for the type of the observed alternations which in the case of dentals and velar result in mutations of consonants (e.g., d → ž, t → č, z → ž, s →š, g → k etc.), but in the case of the labial consonants involve an epenthetic -l (e.g., b → bl', m → ml' etc.).

To sum up, although there are several approaches to the classification of verbs, all of them treat verbs as consisting of the following units: (prefix(es)), root, verbal classifier and inflectional ending. Verbal classifiers allow to distinguish various verb classes which may differ in other aspects such as degree of productivity, type frequency and presence of stem alternations in certain forms. There are differences between the -aj and -i verbs as well as zero suffixed verbs used in the present study with regard to the degree of productivity and the presence of stem mutations or in terms of Feinberg (1996) "morphophonemic stability".

The properties of the -aj class including the unrestricted productivity in comparison to other classes as well as the absence of stem changes in its paradigm may lead to the conclusion that it is the least marked one if one relies on the terminology of the markedness-based accounts (Feinberg, 1996) or that -aj verb stems are fully combinatorial and represent a combination of a root and a stem-formation verbal classifier. Other verb classes including the -i class and unsuffixed classes show either restricted productivity or are not productive at all and verbs belonging to these classes show stem allomorphy in various forms. Thus, such stems of, for example, -i verbs and unsuffixed verbs with allomorphic changes could be arguably lexically-stored. This dichotomy between two types of verb stems has been experimentally tested. In the next chapter I will provide a summary of the main findings.

2.2 Previous Experimental Studies on Russian

Before we proceed to the experiments conducted in this study I will present an overview of the experimental findings with regards to processing of morphologically complex words in Russian. We will start our review with findings from studies examining how derived words in Russian are stored and accessed. I will mostly focus on studies employing the masked priming technique since this method is also used in the present study and the available results could thus be easier compared. However, I will also refer to studies which have used other methods especially in case of the experiments on inflection due to the number of the available masked priming studies.

Kazanina, Dukova-Zheleva, Geber, Kharlamov, and Tonciulescu (2008) examined whether polymorphemic words are already accessed via their constituents during early stages of lexical retrieval as is assumed by an early-decomposition approach. Alternatively, morphemes might be accessed only after the whole-word semantic representation is activated according to the claims of the late-decomposition approaches (Giraudo & Grainger, 2000, 2001). Several studies using a masked priming technique have provided evidence in favour of the early decomposition (Diependaele, Sandra, & Grainger, 2005; Longtin et al., 2003; Rastle et al., 2004). These studies have mostly investigated stripping of a world-final (pseudo)affix, for example, as in *cleaner – clean* vs. *corner - corn* pairs (Rastle et al., 2004).

Kazanina et al. (2008) argued that arguably automatic affix-stripping mechanism should be tested in words with multiple affixes. Thus, they focused on the word-internal derivational affix *-k* used to derive diminutive forms of nouns (e.g., *gor-a* 'mountain' – *gor-k-a* 'little mountain'). Importantly, *-k* is not always a diminutive affix as it can be a part of the root morpheme as in *bulk-a 'bun'* (no such root as *bul-* exists). It is also true that there are also some nouns such as *lunka 'hole'* where -k belongs to the root and yet it is possible to misrepresent it as a suffix, since there is a word *lun-a* meaning 'moon'. Thus, if the result of the initial decomposition was *lun-k-a,* it should be at some point replaced in favour of the correct analysis *lunk-a* 'hole-Nom.Sg'.

The study by Kazanina et al. (2008) compared early stages of processing of pseudo-derived and transparent nouns in an attempt to test whether morphological decomposition is semantically blind and if it is generalizable to cases with multiple affixes. The study included three groups of nouns (transparent, e.g., *gor-a* 'mountain' – *gor-k-a* 'little mountain', pseudo-derived, e.g., *luna* 'moon' – *lunk-a* 'hole' and form, e.g., *part-a* 'desk' – *para* 'pair'). The form condition included primes and targets which differed in one consonant which unlike *-k* could not be misanalysed as a productive nominal affix. For each set of items two types of primes were created that is related and unrelated. The primes were presented for 59ms.

The results show similar facilitation effects for transparent and pseudo-derived conditions and no priming effect in the form condition. This pattern was interpreted by Kazanina et al. (2008) as being in line with predictions of the early decomposition approach indicating that morphological decomposition is always triggered when the word can be perceived as morphologically complex. Furthermore, segmentation of the input is assumed to be exhaustive and is not limited to only one external affix.

Kazanina (2011) also conducted a series of experiments investigating the processing of (pseudo)prefixed words using a masked priming technique. She compared the processing of truly morphologically related words such as *na-rost* 'outgrowth' and *rost* 'growth' to the words which seem to be also morphologically related due to the existence of such prefix in Russian, but where such a relation is in fact false as in *pri-ton* 'den' – *ton* 'tone'. In this experiment Kazanina (2011) also manipulated SOA[8] (40ms/60ms).

The main finding of this study is that under both SOA pseudo-prefixed words, such as *pri-ton* 'den' facilitate processing of the target *ton* 'tone' similarly to the prime and target pairs with a true morphological relationship. No such effect for only orthographically related items has been reported. Kazanina (2011) argues that this pattern strongly supports accounts of obligatory morpho-orthographic decomposition during earlier stages of morphological processing irrespective of the semantic transparency.

Kazanina (2011) also reports facilitation in semantically but not orthographically related pairs such as *pomidor* 'tomato' – *ogurec* 'cucumber'. Although exact reasons remain unclear, this effect is consistent across all experiments. Kazanina (2011) claims that is does not pose a threat to the proposed explanations of the blind morphological decomposition mechanism. In this scenario facilitation found for the pseudoderived items would be hard to explain due to the absence of semantic relatedness between primes and targets. However, semantic relatedness may have indeed enhanced effects of morpho-orthographic decomposition for pairs of transparent primes and targets.

Summing up, these studies by Kazanina et al. (2008) and Kazanina (2011) indicate that decomposition in Russian is not limited to affix-stripping mechanism which applies only to the position to the right of the root. Moreover, this mechanism appears to be completely automatic and to disregard semantic transparency of the derived word.

Heyer and Kornishova (2017) investigated processing of *-ost'* nominalizations in Russian also using the masked priming technique. Since materials and methods of this experiment were adopted for the present study, detailed information will be provided in 2.3.3.1 Design and predictions. Importantly, the study by Heyer and Kornishova (2017) included *-ost'* nominalizations and used base adjectives as target words. In addition to -ost' nominalizations (e.g., *blednost*' 'paleness' – *blednyj* 'pale'), which were included as related primes, conducted experiments also contained simplex nouns as unrelated primes and the identity condition.

Heyer and Kornishova (2017) focused on the role of semantic transparency at short (33ms) and long (67ms) SOA. The results for the derived words at short SOA indicate marginal facilitation (*t*-value of 1,86) for target words following related primes compared to unrelated primes and

[8] SOA – stimulus onset asynchrony.SOA is measured from the beginning of the prime until the beginning of the target and thus denotes the duration of the prime presentation

significantly faster response latencies after identity compared to unrelated primes. These patterns have led Heyer and Kornishova (2017) to conclude that derived items elicited both morphological and repetition priming and that the latter was more robust. Under the short SOA Heyer and Kornishova (2017) found no effect of transparency on morphological priming. Under the longer SOA, however, partial priming effect was modulated by semantics, indicating that facilitation was stronger for prime-target pairs which were more semantically related.

The experiments by Heyer and Kornishova (2017) present further evidence that during initial stages of processing only morpho-orthographic information is utilized whereas semantic information starts to play a role only later at longer SOA when more information from the prime word becomes available to the parser.

In his master's thesis Elin (2013) conducted the cross-modal priming experiment which differed from other studies as it included two types of derived words. The experiment examined the processing of diminutives without stem alternations (e.g., *dom-ik* 'little house' – *dom* 'house') and with stem alternations (e.g., *vnuč-ok* 'little grandson' – *vnuk* 'grandson'). The stem allomorphy illustrated by *k* – *č* alternations is fully predictable. The study included only related and unrelated conditions.

Facilitation effect was found not only for derived nouns with no stem alternation, similarly to Kazanina et al. (2008) and Heyer and Kornishova (2017), but also for nouns with stem alternations. When interpreting these results, one should keep in mind that unlike masked priming studies, the cross-modal priming taps into the more abstract lexical level of processing (Jacob, Fleischhauer, & Clahsen, 2013). Hence other non-morphological sources (e.g., shared form and meaning between related forms) could be responsible for the facilitation effect. In absence of semantically and orthographically related items as control sets it is hard to reject these claims.

Summed up, the experiments by Kazanina et al. (2008), Kazanina (2011) and Heyer and Kornishova (2017) show that derived and even pseudoderived words in Russian are normally decomposed into morphemes during initial stages of processing as captured by the masked priming technique. In what follows I will focus on studies examining processing of inflected words. The majority of the reviewed experiments, however, employed different experimental techniques making the comparison to the current study not always possible.

Several studies made use of the word production task. We will focus mostly on the data obtained from adult native speakers similar to a study by Chernigovskaya and Gor (2000), reexamined later by Gor and Chernigovskaya (2001), and Gor (2003, 2007). The experiment included nonce verbs created from existing verbs by changing initial consonants or vowels. The stimuli were in the past tense plural form and participants were asked to produce the non-past 3rd P. Pl. and 1st P. Sg. forms.

The original existing verbs belonged to 9 verbal classes: -aj, -ej, -(i)j, -(o)j, -a, -e, -i, -ova, -avaj. Among these classes, three pairs have similar past tense forms but differ in their conjugational patterns in the non-past tense forms: -aj and -a, -ej and -e, -(i)j and -i. The verbal stem cannot be identified in the past tense due to the automatic truncation of 'j'. Therefore, it has to be 'guessed' or established based on some sort of statistical probabilities, as assumed by Gor and Chernigovskaya (2004).

The following classes are productive: -aj (11,735 verbs), -i (6,875 verbs), -ova, (2,875 verbs) and -ej (638 verbs). The type frequencies of other classes are extremely low ranging from 3 (-avaj) to 60 (-a) verbs. Based on these values, patterns of productive and high type frequency classes were expected to be generalized more readily than low type frequency stems. However, one should not exclude potential influence of the complexity of the rules defining a paradigm on the rates of generalization. For instance, -aj, -ej and unproductive -(i)j stems have one rule (consonant deletion), whereas -a, -e and, importantly, -i are shaped by application of three rules (Gor & Chernigovskaya, 2001). Thus, while based on criteria mentioned above -aj and -ej patterns should be readily applied to -a and -e verbs, there is a conflicting prediction with respect to -i and -(i)j classes. Based on productivity one could expect a stronger generalization of the -i class, yet complexity of its paradigm may favor the -(i)j paradigm.

Chernigovskaya and Gor (2000) presented the percentages of stem recognition and generalizations rates for each class. These results show that -aj class is recognized in 89.7% of verbs derived from -aj stems and is applied up to 80.9% of the -a nonce stems. This means that even when nonce verbs were constructed from -a verbs they were almost always conjugated as -aj verbs. However, interestingly only in 16.7% of responses an -i pattern was applied to nonce -(i)j stimuli. This generalization rate is low, considering that the -(i)j class consists of only seven members. One could have expected that -i pattern should be applied more often to nonce -i(j) verbs than only in 16.7% resembling generalization rates of the -aj class. Conversely, nonce -i verbs were conjugated as -i(j) verbs in 30% and as -i verbs only in 36.6% of responses. In sum, extremely rare -i(j) pattern is surprisingly generalized more readily than numerous -i type.

This observation allows us to reexamine the Russian verbal system. Traditionally, the -aj class was claimed to possibly represent the default pattern. Gor (2003) suggests that verb classes could be instead classified as belonging to two types 'vowel+j' and 'vowel+ø' and assumes that the former one could be seen as a default. It follows that as the unproductive –(i)j pattern resembles the default pattern, it could have become much stronger and chosen more often for novel verbs. Moreover, as the -i pattern involves stem allomorphy it may be at a disadvantage compared to the default pattern. Thus, competition between the default 'vowel+j' rule and the analogy-based mechanism may account for the -i /-(i)j generalization rates.

Gor (2003) concludes that the 'vowel+j' pattern has the highest type frequency, the most regular inflection and is characterized by the absence of stem allomorphy. However, the generalization rate could be apparently influenced by the type frequency of the class (e.g., if the infinitive ends with -at', then the very likely pattern is -aj, unlikely -a; if with -it', then very unlikely –(i)j and very likely -i). Hence, the default symbolic rule is considered to be general enough, but at the same time is seen to have "different weights depending on the frequency of use of the default pattern with specific vowel in the verbal classifier" (Gor, 2003, p. 72).

Recently, Slioussar et al. (2014) investigated processing of Russian inflection by conducting an fMRI study asking participants to generate 1P.Sg. present tense forms from existing and nonce verb stimuli presented in the infinitive form. Two groups of verbs were included in the study: -aj verbs and verbs from various non-productive classes which were labelled by the authors as irregular. Nonce verbs were split into these two groups as well. The behavioral data have shown the effect of the verb class as participants made fewer errors with -aj verbs compared to other verbs.

The interpretation of the imageing data was more complicated. Slioussar et al. (2014) found that the task elicited greater activation of the fronto-parietal brain network (including the inferior frontal gyrus) for irregular than for regular items. This pattern was hypothesized to be due not to the regularity but rather due to the greater processing load in terms of working memory. An argument confirming this assumption according to Slioussar et al. (2014) would be the increase of activity from real to nonce stimuli. Indeed, they found an overlap of activated brain regions affected by regularity with those affected by the lexicality (verb/nonce verb).

These results were interpreted in line with the single system approach. The inflectional patterns of verbs belonging to -aj class are more frequent and productive than those of irregular classes which presumably makes them more active and easier to access. Thus, the application of such patterns to existing and new verbs is less demanding in terms of cognitive resources.

Further analysis of the same study by Kireev et al. (2015) allowed to dissociate regularity and processing difficulty effects. The authors reported that -aj verbs activated the left inferior frontal gyrus (LIFG) and also bilateral superior temporal gyri (STG) more than irregular verbs thus producing the regularity effect. Furthermore, they found increase in connectivity between the left inferior frontal gyrus (LIFG) and the right anterior cingulate cortex (ACC) in irregular trials related to the greater number of mistakes. This pattern was reversed for regular trials, that is the connectivity was greater in trials for participants who had low error rates.

Kireev et al. (2015) compared their study to the study by Stamatakis, Marslen-Wilson, Tyler, and Fletcher (2005) which examined processing of regular and irregular verbs in English. Stamatakis et al. (2005) found a stronger effect of ACC activity on fronto-temporal connectivity for regular verbs than for irregular verbs. Thus, results involving the ACC differ across two studies, which Kireev et al. (2015) attributed to the difference in the morphological structure of regular and irregular verbs in English. They claimed that in English regular verbs are morphologically complex, whereas irregular verbs are simplex.

Note however, that the claim regarding simplicity of the irregular forms in English is questionable. It could be argued, that some past tense forms such as *kept* or *burnt* are also morphologically complex and are produced via affixation followed by the phonological readjustment to the stem (Fruchter, Stockall, & Marantz, 2013). Kireev et al. (2015) assume that irregular verbs in Russian are at least partially decomposed by being stripped off the infinitive ending. This combination of retrieval from the memory and some degree of decomposition makes irregular verbs in Russian arguably more difficult to process than -aj verbs and irregular verbs in English. However, if one would also treat irregular verbs in English as morphologically complex it would be unclear whether they would still be the easiest to process.

The processing mechanisms sketched by Kireev et al. (2015) could be viewed as being in line with the modified version of the dual-mechanism approach, because according to Kireev et al. (2015) it would normally admit only one default rule and would require storage of all other forms. The single mechanism approach which takes only the type frequency into consideration is argued to be unable to explain the available data. In general, the authors argue in favor of hybrid models which consider multiple rules of different status similarly to Gor (2003).

The classes tested in Kireev et al. (2015) differ in many aspects, such that the -aj class is productive and is of a high type frequency, whereas ‘irregular’ verbs represent patterns which are not productive and of a low type frequency. Moreover, -aj class may also be default if not on its own then as member of the more abstract ‘vowel +j’ pattern if one assumes that the default rules do not necessarily need to specify a vowel (Gor, 2003). Furthermore, the observed differences could be due to yet another factor as the classes differ in terms of the presence or absence of stem changes which are typical of the non-suffixed verbs. That is why additional studies are required to examine the processing of other classes where these factors could be studied separately.

Taking into account the arguments above, several studies investigate the processing of other classes as well. Moreover, as researchers employed a priming technique their results are more comparable to the present study. One example is the study by Gor and Jackson (2013), the materials from which were partially adopted for the present experiment.

The study by Gor and Jackson (2013) included three types of verbs: regular -aj verbs, semiregular -i verbs and irregular verbs (verbs from minor classes with idiosyncratic stem changes). As noted by Clahsen (2016) the labels chosen by Gor and Jackson (2013) are misleading as they mix together properties of inflectional and stem-formation morphology and apply English-influenced terminology to stem-formation processes. The contrasts between verbs have less to do with inflection than with stem types. Compare: *igr-aj-u* 'play 1P.Sg. Pr.' – *igr-a-t'* 'to play' and *koš-u* 'mow 1P.Sg. Pr.'' – *kos-i-t'* 'to mow'. Note that the ending -u is identical in both cases in contrast to past tense forms of English verbs (e.g., *played* and *swam*). Stem properties, however, may differ due to alternations in certain forms, for example, as observed in verbs from the -i class as in *koš-u* 'mow 1P.Sg. Pr.'' – *kos-i-t'* 'to mow'. All verbs were further split into two groups (high-frequency and low-frequency) based on the lemma frequency ranges.

Gor and Jackson (2013) employed an auditory priming paradigm comparing facilitation effects in native (and non-native) speakers of Russian having included only identity and related conditions. The authors found robust priming effects for native speakers across all verb types for both low and high frequency sets. This finding was interpreted in favor of the initial automatic decomposition of all inflected verbs in Russian. The following step arguably involves either further decomposition or access of stem representations at the lemma level. It was also hypothesized that highly frequent forms could be stored as whole-word representations.

Access of irregular verbs with complex stem allomorphy was found to be effortful only for non-native speakers as Gor and Jackson (2013) observed a developmental trajectory for L2 showing stronger priming with increasing proficiency especially for low-frequency items. The question remains, whether the observed effects including those measured in native speakers are general? Would these effects remain if primes and targets were presented in a different modality (e.g., visually) when primes are also less perceptually salient due to being masked. It is also unclear how robust the observed effects are and whether they would remain if a larger sample of participants is tested. A relatively low number of participants (11 adult native speakers) and observations per condition (e.g., less than 100 observations for highly-frequent irregular verbs) calls for further investigation of the observed effects.

Svistunova, Gazeeva, Elin, and Chernigovskaya (2009) examined the processing of verbs from productive -aj, -ova, -i (Feinberg, 1996; Timberlake, 2004) and unproductive -a classes in the cross-modal priming experiment. Verbs from all classes were further divided based on the lemma frequency. Significant interactions between the verb class and the condition as well as between the frequency and the condition were found. The results have shown that highly frequent verbs yield a full priming effect in contrast to the partial priming reported for low frequency verbs. Furthermore, a full priming effect was found for -aj and -ova verbs, whereas for -i and -a verbs only a partial priming effect was shown. These findings were interpreted by Svistunova et al. (2009) as being neither in favor of the single nor the dual-route approaches for the reasons discussed below.

On the one hand, the differences between the -aj class which is often considered to be the default one and the -a class are in line with the assumptions of the dual-route mechanism. On the other hand, productive -i and -ova classes differ with regard to priming effects, such that -i class produced a partial priming effect, whereas -ova class yields a full priming effect. This was presumed to run against the dual-route model. However, this interpretation is correct if productivity is seen as the only defining and characteristic feature of the default pattern as nondefault conjugations could also show some limited productivity. The dual-mechanism approach acknowledges that “the rule could fail to apply to a new word if the word is so similar to irregular words in the memory that analogy is irresistible” (Pinker, 1999, p. 214). Therefore, the productivity of the -i class could be driven by analogy in contrast to -aj and -ova classes which could be seen as members of the default ‘vowel +j’ pattern.

In addition, whereas a full-priming effect was found for all high-frequency verbs, the verb class modulated processing of low-frequency verbs such that only -aj and -ova verbs produced full priming effects in contrast to -i verbs and -a verbs. These findings were in their turn interpreted as being inconsistent with the associative single-mechanism approach as it postulates the storage of all forms in the associative memory system. As a result, the higher frequency of a word should lead to stronger memory links between its forms and to greater facilitation.

Therefore, according to Svistunova et al. (2009) the magnitude of priming should depend only upon word frequency. The finding that some low frequency verbs, that is those belonging to -aj and -ova classes, differ from others was deemed by Svistunova et al. (2009) to be incompatible with this prediction. Unfortunately, the role of other factors such as phonological similarity which also plays a significant role in connectionist models (Gonnerman, Seidenberg, & Andersen, 2007) has not been assessed or controlled for by including a control set of phonologically related items. Therefore, the claim that the results contradict the assumptions of the single-mechanism approach is too strong.

The authors hypothesized that differences in facilitation effects might be due to the properties of the verbs. Whereas stem changes in verbs belonging to -aj and -ova classes are relatively simple (i.e., automatic consonant truncation for -aj and suffix alternation for -ova classes), the alternations in other classes are more complex and affect roots of the verbs (e.g., *nos-i-t'* ‘to carry’ – *noš-u* ‘carry 1P SG’). Indeed, the differences between -ova and -i class are hard to explain without considering the properties of the alternations, since two verb classes are similar in terms of productivity and relatively high type frequency.

In contrast to the auditory priming study by Gor and Jackson (2013) the cross-modal priming experiment by Svistunova et al. (2009) showed processing differences between verbs varying in the complexity of root/stem allomorphy. Unfortunately, Svistunova et al. (2009) have not explicitly discussed the contrast between the ‘vowel + j’ and ‘vowel + ø’ rules which may account for the differences in priming effects found for -ova and -i classes, as only -ova class may be included within the scope of ‘vowel + j’ pattern taking into consideration suffix alternation (ova / uj). One should keep in mind that these explanations are not mutually exclusive as the non-default pattern is often associated with a more complex conjugational paradigm with stem changes (Gor, 2003).

To sum up, several previous studies on inflection have observed the differences between various verbal classes and others not. The discrepancy observed, for instance, between studies by Svistunova et al. (2009) and Gor and Jackson (2013) may be, as discussed, due to the role of the chosen experimental paradigms, presentation modalities and other factors. Thus, it remains to be tested whether overall differences in priming effects for various types of verbs found by Svistunova et al. (2009) are robust and morphological in nature (and are not a byproduct of, for example, the degree of phonological overlap) and could be replicated using other experimental methods.

The masked priming paradigm used in the present study is considered to tap into the initial stage of morphological processing (Jacob et al., 2017). Hence it would allow us to better disentangle the effects reflecting morphological structure and the differences between various types of verbs from effects stemming from the semantic relatedness or the surface form properties. To additionally control for these effects the present study includes control items related only orthographically or semantically. Until now the role of morphological properties of the word has been only poorly investigated in masked priming experiments despite its importance for the theories of word recognition. This is especially true for accounts which assume a blind affix-stripping mechanism as hypothesized by McCormick, Rastle, and Davis (2008). However, this hypothesis is based on the findings from testing pairs such as *adorable – adore* in English and therefore it is not immediately clear whether more extensive alternations found in Russian would have an impact on the decomposition mechanism.

Furthermore, as claimed by Aronoff, Berg, and Heyer (2016) even presumably robust processing mechanisms such as an early automatic decomposition may be language specific to some extent and depend on the salience of the affix. These are determined by the properties of the spelling system which either more consistently distinguishes affixes from the homophonous final letter sequences of the monomorphemic words as in English or French or less as in languages like German. The experiments reported in the next chapter would also allow to look at the phenomena of morphological processing from a cross-linguistic perspective investigating word recognition in Russian. Considering the dearth of studies on initial stages of morphological processing in Russian, it remains to be seen whether mechanisms posited for English or French would be equally effectively applied to Russian.

Note that theories assuming a blind morphological decomposition are often based on studies examining the processing of derived words only, whereas several experiments indicate that mechanisms underlying processing of complex words may differ reflecting linguistic differences between derivation and inflection (Jacob et al., 2017; Kırkıcı & Clahsen, 2013). The reported differences highlight the importance of comparing various groups of speakers in order to refine existing theories which are often based on data from a group of healthy young participants in mid-twenties. They do not consider other groups such as L2 speakers, heritage speakers or older adults.

For instance, both mentioned studies by Jacob et al. (2017) and Kırkıcı and Clahsen (2013) report differences in priming effects between inflected and derived words only when a group of L2 speakers was compared to a group of typically tested young and fit native speakers. However, the conditions under which these differences become detectable as well as whether the linguistic differences are restricted only to non-native speakers remain unclear. The two experiments on Russian will focus on yet another group of speakers which has never been, to the best of our knowledge, investigated with regard to this question. This group is that of older adults.

One may expect to observe effects of ageing which may be either general or specific to particular phenomena, especially the processing of forms which rely more on the storage-based mechanism of recognition, such as inflected forms with stem alternations. If the processing of derived words is also largely lexically-mediated in native speakers as Jacob et al. (2017) interpret the conclusions of Kırkıcı and Clahsen (2013), older adults may face challenges processing these forms compared to younger adults and would show less facilitation. This assumption is based on indications that declarative memory subserving lexical storage is negatively affected by ageing (Harada et al., 2013; Rönnlund et al., 2005). Alternatively, one could predict that "greater age and, thus, greater experience with complex forms facilitates storage-based access" (Reifegerste et al., 2017, p. 485). In this case ageing could be seen as an advantage which would yield stronger priming for derived words as well as inflected forms with stem alternations.

We are not aware of any studies on Russian which have investigated the processing of polymorphemic words in ageing. Therefore, the question as to whether the effects reported in the literature with respect to the processing of complex words in Russian would undergo any age-related changes remains open. As mentioned earlier, answering this question is important for multiple reasons including constraining theories of morphological processing, assessing the role of age-related changes as well as examining phenomena from a cross-linguistic perspective.

The experiments on the processing of derived as well as inflected words in Russian described in following chapters will attempt to address these questions.

2.3 Experiments

2.3.1 Participants.

39 younger[9] and 37 older native speakers of Russian, living in Saint Petersburg, Russia, took part in studies examining the processing of derived and inflected words in Russian on the same day. All participants gave their informed consent and were paid for their participation. They had no history of neurological or language-related impairments and had normal or corrected-to-normal vision and hearing.

See Table 1 for demographic details on all participants recruited for the experiment.

[9] All participants were recruited and tested specifically for the purposes of this study and differed from those tested by Heyer and Kornishova (2017) who developed the design and materials of the experiment (see more in Chapter 2.3.3.1)

Table 1

Demographic Information on Participants in Studies on Derivation and Inflection in Russian

	Older group			Younger group		
Number	37			39		
Sex	11 males, 26 females			11 males, 28 females		
	mean	SD	range	mean	SD	range
Age	67.6	8.4	51-84	23.2	3.7	18-31
CERAD	81.8	8.5	68-97	-	-	-

All participants included in the group of older adults completed the neuropsychological test battery of the Consortium to Establish a Registry for Alzheimer's Disease (CERAD-Plus; www.memoryclinic.ch). The CERAD composite score (Chandler et al., 2005) is the sum of several tests and included a participant's score for Verbal Fluency (Animal Naming), the modified Boston Naming Test, Constructional Praxis as well as Word List Learning, Recall, and Recognition Discriminability. The maximum possible score is equal to 100.

Five of these subtests (Verbal Fluency, Boston Naming Test, Word List Learning, Word List Recall, Word List Recognition) directly examine verbal memory performance. Thus, the CERAD score may be viewed as a proxy of verbal memory. All participants in our study on Russian completed neuropsychological test battery so that the score could be then compared to the score from the group of older German adults.

However, unlike for German, there are no available normative values for Russian. Moreover, when available, CERAD scores are country specific (Paajanen et al., 2010). Even though the available score thus serves for comparison purposes, it should be noted that participants scored within 1.5 SDs from the population mean as reported by Berres, Monsch, Bernasconi, Thalmann, and Stahelin (2000) for the German translation of the CERAD neuropsychological battery. Moreover, the average score as well as the range is slightly higher than in the normal control group examined by Chandler et al. (2005) using English version of CERAD (mean score uncorrected for demographic variables is 79.7 (SD=9.0, range 52-98). Hence, in absence of normative values for Russian one could interpret the obtained ratings of cognitive performance as being typical in healthy ageing, even though this conclusion should be treated with caution.

As it was established after the experiment, the data from two participants belonging to the group of older adults had to be removed prior to any further analyses described in the following chapters due to the poor eyesight which was not corrected by wearing glasses and in one case further complicated by the cataract violating our recruitment criteria. The decision to remove such participants was motivated by the importance of the intact visual perception for masked priming experiments which imply fast visual presentation of the stimuli on the screen. Thus, the remaining number of the older speakers of Russian was reduced to 35 participants.

2.3.2 Procedure.

Participants were tested individually in a dimly lit room in a quiet environment using the DMDX testing software (Forster & Forster, 2003) for stimulus presentation and data collection. Each participant was randomly assigned to one of the presentation lists.

The experimental trial started with a 500ms blank screen followed by a forward mask consisting of hash marks for 500ms. Forward mask was followed in its turn by a prime word displayed for 66.68ms. This duration corresponds to 4 screen refresh rates of the laptop used for the experiment. The target word appeared immediately after the presentation of the prime and remained visible for 500ms.

Participants were instructed that they would see a number of existing Russian words and nonwords on the computer screen and were asked to decide as quickly as possible whether the words they see exist in Russian or not by pressing either YES or NO buttons on the Logitech gamepad. RT measurements started with the presentation of the target word. If the participant did not produce a response within 3000ms, a new trial started.

The forward masks, primes and targets were presented in the center of 15-inch laptop screen the screen in white letters against the black background. Whereas the forward hash masks and targets were presented in bold Comic Sans Ms font (size: 28), we chose Bookman Old font (size: 28) for prime words to further mask their presence.

Before the experimental session, each participant was given a practice section consisting of 10 prime-target pairs. Afterwards each participant was given a list of 30 words and were asked to mark the words they have seen. This was done to ensure that participants paid attention to the stimuli and remained unaware of the primes. In the end of the experimental session, all participants were asked to describe what they saw on the screen during the experiment.

The experiment on derivation lasted approximately 25 minutes while the experiment on inflection took about 30 minutes. There was a pause between two experiments. The order of experiments varied across participants to minimize fatigue effects.

2.3.3 Experiment I. Derivation.

2.3.3.1 Design and predictions.

The design and materials of the masked priming experiment on the processing of derived words in Russian are taken from the study by Heyer and Kornishova (2017) with the permission of the authors. In what follows the design and materials will be described in more detail.

The design developed by Heyer and Kornishova (2017) comprised three item groups: a morphological, a semantic and an orthographic one. The morphological set consisted of 30 adjectival targets (e.g., *gordyj* 'proud') preceded either by the corresponding *-ost'* nominalization (e.g., *gordost'* 'pride'), an identity prime or a matched unrelated control prime word (e.g., *vedro* 'bucket'). In the unrelated conditions the primes were nouns which were semantically and orthographically unrelated to the target.

It should be mentioned that even though -ost' has two allomorphs such as *-est* and *-nost'* both are extremely rare and, as discussed, are selected in the phonetically restricted context. Furthermore, it does not lead to any stem changes, except for a potential stress shift for adjectives ending in stressed *-oj*. In our set there were 5 such cases (*tupoj* 'stupid', *živoj* 'alive', *molodoj* 'young', *syroj* 'moist', *suhoj* 'dry').

Due to the fact that primes and targets in the morphological items set are not only morphologically but also semantically and orthographically related, two control sets of items were added which are either semantically or orthographically related. This would allow to check whether the facilitation effect, which we might find in our set of the morphologically related items, is truly morphological or is due to other types of relatedness between primes and targets. In each group there were 21 experimental targets.

All matching values cited below were also calculated by Heyer and Kornishova (2017) even though they are not provided in the original published study.

Orthographically related pairs were chosen to mirror the orthographic relatedness in morphologically related pairs as closely as possible using Match Calculator by Colin Davis (http://www.pc.rhul.ac.uk/staff/c.davis/Utilities/MatchCalc/). The absolute amount of overlap was assessed by estimating how many letters from the target also appeared in the prime and the value could vary between 1 (full overlap) and 0 (words have no common letters). The mean overlap for morphologically related items was 0.5 (SD = 0.05), the number of overlapping letters was 3.9 (SD = 0.62). For the orthographically related items the mean overlap was 0.53 (SD = 0.06), the number of overlapping letters was 3.9 (SD = 0.43). The overlap was also assessed using the SOLAR model, which takes into account the position of common letters in the two words.

These estimates were compared using Welch t-test and they did not differ in the two item sets, neither for the absolute overlap (t = 0.7, df = 28.5, p = .4) nor for the overlap score calculated based on the SOLAR model (t = 0.3, df = 26.6, p = .7).

Semantically related items were chosen based on a web-based questionnaire developed by Heyer and Kornishova (2017). Native speakers of Russian were asked to rate the semantic relatedness of words on a scale from 1 (totally unrelated) to 7 (identical). For the morphologically related items, the mean relatedness was 5.3 (SD = 0.29) and the range was 3.8 to 5.8, for the semantically related pairs it was 5.0 (SD = 0.91) and the range was 3.6 to 6.5. The difference between the two groups was not significant (t = 1.5, df = 25.7, p =.14).

Identity and control primes were also used in groups of semantically and orthographically related items. Control primes were chosen so that they have no obvious formal or semantic similarity with their targets (e.g., *bober – suhoj* ‘beaver - dry’) and matched the test primes with respect to frequency and length.

The targets in three item groups were matched for both lemma and word-form frequency. As all suitable semantically related items had less letters than morphologically related items, they were matched based on the number of syllables.

The means, standard derivations and results from t-tests or one-way ANOVA comparisons conducted by Heyer and Kornishova (2017) are provided bellow in the Table 2. The frequency counts are based on the New Frequency Dictionary of Russian Vocabulary (Lyashevskaya & Sharov, 2008).

Table 2

Length and Frequency Information for Three Item Sets in the Experiment on Processing of Derived Words in Russian

	Morphologically related items	Semantically related items	Orthographically related items	Statistics on comparisons
Target lemma frequency	117.8 (SD = 128.7)	109.7 (SD = 103.1)	152.3 (SD = 170.7)	F (2,69) = .1, p = .82,
Target word-form frequency	16.6 (SD = 19.7)	23.6 (SD = 23.5)	23.5 (SD = 24.0)	F (2,69) = 1.3, p = .27
Length of primes (letters)	7.8 (SD = 0.78)	-	7.5 (SD = 0.84)	t = 1.1, df = 40.1, p = 0.25
Length of targets (letters)	5.8 (SD = 0.77)	-	5.7 (SD = 0.73)	t = 0.4, df = 41.8, p = 0.6
Prime length in syllables	2.0 (SD = 0.12)	2.0 (SD = 0.13)	-	t = 1.4, df = 32.3, p = 0.1
Target length in syllables	1.9 (SD = 0.33)	2.5 (SD = 0.5)	-	t = 1.5, df = 27.9, p = .13

Experimental items were distributed across three presentation lists according to the Latin Square Design so that each list had only one out of three prime/target pairs from each of the three experimental sets.

In each item group, the items were distributed over three lists that were matched as closely as possible in terms of mean word-form and lemma frequency, as well as length.

Heyer and Kornishova (2017) mixed 72 critical items with 328 fillers, making it 400 items in the whole experiment (see Appendix A for the list of all critical items). Half of the targets, as well as half of the primes were existing words, and another half – nonwords constructed by changing one or two letters of an existing Russian words. Targets included adjectives (115), nouns (135) and verbs (150). The same was true for the primes (123 adjectives, 125 nouns, 152 verbs). All filler words were in their dictionary forms: nouns in Nominative Singular (or Plural, if they had no Singular form), verbs in infinitive, adjectives in Nominative Singular masculine form. In order to compensate for fatigue effects, each of the three lists was presented in the reverse order approximately for half of the participants. The overall relatedness ratio was 12%.

Based on previous research on morphological processing and ageing several potential outcomes discussed in previous chapters could be predicted:

1) Similar facilitation effects for both age groups which could indicate robust decomposition-based processing in older adults (Duñabeitia et al., 2009; Kavé & Levy, 2004)

2) Less facilitation in older adults which could indicate lexically-mediated processing and its decline due to the weaker memory links between lexical entries (Clahsen & Reifegerste, 2017)

3) Alternatively, more facilitation with advancing age which could indicate greater experience of older adults which boosts storage-based access and lexically-mediated processing (Reifegerste et al., 2017)

4) Higher accuracy and slower response latencies in older adults indicating speed-accuracy trade-off as predicted by Ramscar et al. (2014)

2.3.4 Experiment I. Analysis.

2.3.4.1 Data analysis.

Data cleaning was first carried out based on the accuracy rates of participants and other factors such as whether the participants reported being able to notice and read primes.

These criteria led to the exclusion of 4 out of 39 participants in the control group of younger adults. The participants were removed for the following reasons: two participants were removed for being able to read the primes and even establish the relationship between primes and targets (especially in the set of semantically related items). Participants reported being able to read around two thirds of primes in the interview after the end of the experiment. Inclusion of such participants in the analysis would have undermined the main theoretical assumptions of the masked priming paradigm which relies on subjects' unconscious perception and processing of primes in contrast to, for example, the cross-modal priming paradigm. Furthermore, one participant was removed for extremely low accuracy (below 50%). Another one participant was also removed due to the relatively low accuracy (around 80%) compared to the average accuracy and extremely slow reaction times. The average accuracy of the remaining 35 participants calculated for all 410 stimuli was in total around 95.5% with the mean RT of 691.5ms and SD of 204.7ms. The accuracy of around 80% seemed to be an outlier and not typical of a healthy native speaker. Furthermore, the mean RT of this young participant was around 1402ms, which is far beyond the overall mean RT plus 2SD and appears to be extremely low in comparison to the average values (it corresponds roughly to a sum of the mean RT and 3.5SD). Based on these values it was decided to remove this participant.

In the group of older adults 3 participants out of the remaining 35 were removed. The participants had to be excluded from further analyses for following reasons: one participant was removed due to the accuracy around 50% (the participant mixed “Yes” and “No” buttons on the gamepad after one of the pauses), another one participant was removed due to the technical issue. Yet another one participant was removed due to the low accuracy. While the accuracy of this participant in the experiment on derivation presented below was around 80%, which is much lower than the average accuracy of 94.4% of the remaining participants, the accuracy in the experiment on inflection presented in 2.3.5 Experiment II. Inflection is substantially worse and is only around 70% compared to the mean accuracy of around 93%. Since we wanted to keep our sets of data parallel, the decision was made to remove the participant from both analyses mostly based on extremely low values in the experiment on inflection which are much lower than those of healthy older adults, although the accuracy rate in the experiment on derivation is also noticeably below the average values of older native speakers of Russian[10].

Further data cleaning included removing of all incorrect responses and timeouts (2.82% for the group of older adults and 2.61% for the group of younger adults). In order to normalize the distribution, we conducted analyses based on the transformed RTs (inverse transformation) and applied cutoff points to remove extreme values which were higher or lower than 2SD from the mean RT per participant. This has led to removal of additional 5.3% of the remaining data for the older group, and 4.97% of the data for the control group of younger adults.

We analyzed RTs with mixed-effects linear regression models with crossed random effects for participants and items (see Baayen, Davidson, and Bates (2008)) using the languageR package (Baayen, 2008) and the lme4 package (Bates, Maechler, Bolker, & Walker, 2014).

The model we fitted included the two fixed effects Prime Type (Morphological, Semantic, Orthographic) and Condition (Unrelated, Related, Identity) and their interaction. As predictors the models included Trial Number (the position of the item in the presentation list; centered) to control

[10] The inclusion of this participant in the analyses of the experiment on derivation presented below does not change any of the reported effects.

for trial-level task effects, such as fatigue, Reaction Time on the Previous Item (inverse transformed, centered), Word Form frequency of the target (centered), Lemma frequency (centered) and Length, that is number of letters (centered).

Accuracy data were analyzed with generalized linear models with a binomial link function.

2.3.4.2 Results.

Table 3 illustrates mean accuracy rates, mean response latencies as well as standard deviations of RT data in each condition for groups of older and younger adults.

Table 3

Mean RTs, Standard Deviations and Mean Accuracy for Three Items Sets by Condition for Older and Younger Adults

		Older adults			Younger adults		
		Identity	Related	Unrelated	Identity	Related	Unrelated
Derived	RT	664.9	669.4	713.7	536.1	564.2	593.1
	SD	135.2	130.6	137.5	110.4	131.9	109.3
	Accuracy (%)	91.6	94.1	88.4	92.3	92.6	88.9
Orthographic	RT	646.6	697.4	701.1	536.0	589.6	596.8
	SD	135.6	127.5	133.1	117.8	115.9	123.7
	Accuracy (%)	93.3	87.5	87.9	95.5	87.3	92.7
Semantic	RT	608.2	673.5	687.2	519.9	568.8	573.8
	SD	106.8	128.0	114.0	121.4	116.9	112.3
	Accuracy (%)	96.9	96.0	93.3	96.3	97.1	91.8

Since the main goal of this study was to investigate morphological processing in older adults, our analysis in this chapter focused on the data obtained from the group of older adults while considering younger adults to be a control group.

The accuracy analysis for the group of older adults revealed more accurate responses after related derived primes than after unrelated primes (β= -0.847, SD= 0.307, z-value= -2.760, p=.005) and significantly more errors after orthographically related primes compared to identity primes (β= 0.816, SD= 0.357, z-value= 2.285, p= .022). Moreover, the interactions between Prime Type (morphologically vs. orthographically related) and Condition (related vs. unrelated) as well as between Prime Type and Condition (related vs. identity) are significant (β= 0.907, SD=0.435, z-value= 2.085, p= .037 and β= 1.269, SD= 0.481, z-value= 2.637, p= .008, respectively).

To examine response patterns of older adults in more detail we fitted a mixed-model effect to the latency data. The reference levels for Prime Types (morphological / semantic / orthographic) were adjusted accordingly so that all RT patterns could be examined in one model. See Table 4 for the model.

Table 4

The Best-fit Model for the RT Data from Three Sets for the Older Participants in the Study on Derivation in Russian

Random effects:		Variance	Std.dev.	Correlation	
Item	Intercept	0.0054573	0.07387		
ID	Intercept	0.0344047	0.18548		
	Condition [unrel – rel]	0.0005645	0.02376	-0.99	
	Condition [ident – rel]	0.0005324	0.02307	0.68	-0.75
	Residual	0.0337202	0.18363		

Fixed effects:	Estimate	Std. Error	t value
Length	0.07523	0.009666	0.78
Lemma frequency	-0.001.295	0.00004509	-2.87
Trial number	-0.002517	0.00003456	-7.28
Word form frequency	-0.004.70	0.0006220	-0.76
RT on previous item	0.05487	0.01789	3.07
Relevelled for Morphological Set:			
Condition [unrel – rel]	0.1029	0.01584	6.49
Condition [ident – rel]	-0.01598	0.01567	-1.02
Relevelled for Semantic Set:			
Condition [unrel – rel]	0.03513	0.01845	1.90
Condition [ident – rel]	-0.1603	0.01819	-8.81
Relevelled for Orthographic Set:			

Condition [unrel – rel]	0.005766	0.01912	0.03
Condition [ident – rel]	-0.1367	0.01883	-7.26
Effect of Set on RT [for related condition]			
Set [orth – morph]	0.08246	0.02719	3.03
Set [seman – morph]	0.02716	0.02863	0.95
Set [orth – seman]	0.05530	0.03076	1.80
Interaction of Condition and Prime Set			
Set [orth – morph]: Condition [unrel – rel]	-0.1023	0.02411	-4.24
Set [orth – morph]: Condition [ident – rel]	-0.1207	0.02383	-5.06
Set [seman – morph]: Condition [unrel – rel]	-0.06773	0.02358	-2.87
Set [seman – morph]: Condition [ident – rel]	-0.1443	0.02331	-6.19
Set [seman – orth]: Condition [unrel – rel]	-0.03455	0.02590	-1.33
Set [seman – orth]: Condition [ident – rel]	0.02363	0.02553	0.93

The results of the model indicate that for the group of older adults derived items as well as primes yield significantly faster responses than unrelated items (t = 6.49) and equally fast responses compared to the identity condition (t = -1.02). This pattern indicates full priming for derived words in the group of older adults.

To make sure these effects are not simply due to the semantic relatedness or orthographic overlap we examined RT patterns in these two sets. The presentation of orthographically related primes to the targets has not led to faster responses compared to unrelated items (t= 0.03), whereas response latencies after related primes were significantly slower than after identity primes (t= -7.26), indicating the absence of a facilitation effect.

The response latencies after semantically related primes were also slower compared to identity primes (t= -8.81). However, in contrast to the pattern found in the set of orthographically related primes and targets, the presentation of primes semantically related to the targets produces faster responses than after unrelated primes with the facilitation effect almost reaching statistical significance (t= 1.90 which corresponds to approximately p= 0.056).

Thus, in principle it is possible that the facilitation effect found after the presentation of derived primes compared to unrelated primes could be due to semantic relatedness between prime-target pairs. However, a mixed effect model shows a significant interaction of Prime Type (morphological vs. semantic) and Condition (related vs. unrelated), indicating much stronger derivational than semantic priming (t= -2.87) which shows that facilitation effects observed for derived items are distinguishable from facilitation in the set of merely semantically related items. Furthermore, the interaction between Prime Type and Condition (related vs. unrelated) is also significant for comparisons between orthographic and morphological sets (t= -4.24). Taken together, these findings indicate a robust priming in the set of derived items independent from pure semantic relatedness or orthographic overlap in the group of older adults. Moreover, priming for derived words is also numerically larger than a combined facilitation effect for semantically and orthographically related items (44ms vs. 18ms).

Following the approach by Heyer and Kornishova (2017) we also investigated the role of semantic transparency in processing of derived words. To test for the semantic transparency effects we examined the interaction of Condition (unrelated vs. related; identity vs. related) and Transparency (centred semantic transparency ratings). Similarly to Heyer and Kornishova (2017) we hypothesized that the priming effects for more opaque items should be weaker than for more transparent items which should lead to the significant interaction. Our analyses have not found any indications of the significant interaction effects. The interaction of Condition (unrelated vs. related) and Transparency was far from being significant with t= -0.11 similarly to the interaction of Condition (identity vs. related) and Transparency with t= 1.09. Thus, in contrast to the study by Heyer and Kornishova (2017) semantic transparency does not appear to affect processing of derived words by older adults in our study even though we used the same SOA of 67ms for which the semantic transparency effect was reported. To examine whether this might be due to the age of our participants we will examine the same effect in the group of younger speakers in the section below.

2.3.4.2.1 Between-group comparisons.

In order to find out whether accuracy patterns found in the group of older adults differed from patterns found in the control group of younger adults the best-fit generalized linear model which included Prime Type (derived, semantic and orthographic primes), Condition (identity, related, unrelated), Group (old / young) was compared to a minimally different model with three two-way interactions. The comparison of two models revealed that inclusion of interaction does not improve the model fit ($\chi^2(6)$= 3.906, p= .68) showing similarities across two groups.

To further examine this pattern, we explored accuracy patterns for the group of younger adults in the set of morphologically related primes. The analysis showed more accurate responses after the related derived primes than after the unrelated primes (β= -0.554, SD= 0.277, z-value= -

1.998, p= .045). The interactions with the group of older adults are not significant as well as the main effect of Age (*p*s >.33). To additionally assess the claims assuming higher accuracy of older adults compared to younger, the accuracy rates were also compared for the unrelated condition only. This comparison has not found any evidence to support this claim because error rates do not statistically differ (β= 0.206, SD= 0.194, z-value= 1.059, p= .28).

Similarly to our analysis of the accuracy rates, we fitted an omnibus model which included Prime Type (derived, semantic and orthographic primes), Condition (identity, related, unrelated), Group (old / young) to the latency data. This model was compared against a minimally different model with three two-way interactions. The comparison of two models demonstrated that interaction term does not improve the model fit showing similarities across two groups ($\chi^2(4)= 3.804$, p= .43).

The omnibus model, however, produced a strong effect of slowing of older adults compared to younger adults, as response latencies averaged across all conditions and sets increase with advancing age (β= -0.2862, SD= 0.05169, t= -5.54). To additionally test the claim assuming slower RTs of older adults compared to younger, the response latencies were compared only for the unrelated condition. The response latencies of younger adults are indeed significantly faster in the unrelated condition similarly to the overall pattern (β= -0.2648, SD= 0.04564, t= -5.80).

Even though priming effects appear to be similar for the two groups, we fitted an additional model to the data of the control group of younger adults to separately investigate priming effects. It would allow us to assess in greater detail the facilitation effects for this group, which is of interest considering the existence of large group differences between groups of older and younger adults (e.g., in terms of overall speed of RT), as well as directly comparing priming effects in the morphological set (see Table 5).

Table 5

The Best-fit Model for the RT Data from the Morphological Set in the Study on Derivation in Russian (with a Group of Younger Adults as a Reference Level)

Random effects		Variance	Std.Dev.
ID	Intercept	0.047905	0.21887
ItemID	Intercept	0.003563	0.05969
	Residual	0.044075	0.20994

Random effects	Estimate	SE	t-value
Lemma	-0.00007282	0.00005206	-1.40
Trial number	-0.0001865	0.00004413	-4.23
Length	-0.0003629	0.01266	-0.03
RT on previous item	0.08523	0.02065	4.13
Facilitation effect:			
Condition [unrel – rel]	0.1085	0.01674	6.48
Condition [ident – rel]	-0.07774	0.01655	-4.70
Main Effect of Age			
Age [Young – Old]	0.2987	0.05471	5.46
Interaction of Condition and Group			
Group [Old – Young]: Condition [unrel – rel]	-0.004764	0.02414	-0.20
Group [Old – Young]: Condition [ident – rel]	0.06339	0.02392	2.65

These results indicate that the presentation of the related derived primes elicited much slower responses than responses in the identity condition (t= -4.70) showing that derived primes were not as efficient primes as identity primes in the group of younger adults. Crucially, however, related derived primes produced much faster responses to the target words compared to unrelated primes (t=6.48). Moreover, the magnitude of the facilitation effect (for related vs. unrelated conditions) between the two age groups does not statistically differ showing no reduction of a priming effect with advancing age (t= -0.20).

Similarly to the analysis of the data from older adults we also analyzed the role of the semantic transparency effects on processing of the derived words in younger adults. To test for the semantic transparency effects we included the interaction of Condition (unrelated vs. related;

identity vs. related) and Transparency (centered semantic transparency ratings) into our models. Similarly to the results in the group of older speakers, the interaction of Condition (unrelated vs. related) and Transparency was also not significant with t= 0.58 as well as the interaction of Condition (identity vs. related) and Transparency with t= 0.92. Thus, in contrast to the study by Heyer and Kornishova (2017) semantic transparency does not appear to affect processing of derived words in the group of younger adults as well. These results, considering similar mean age (23 vs. 29) as well as the number of participants (32 vs. 30) in both studies, cast doubts on the reliability of this effect reported by Heyer and Kornishova (2017) especially considering the absence of significant effects in both our groups (67 participants in total).

Overall, our findings show robust facilitation effects for derived items in the group of younger adults as well as older adults. Older adults show even more facilitation than younger adults, who produced significantly longer RTs than older adults after related primes compared to identity primes (t= 2.65). This smaller difference in RTs between two conditions observed in the group of older adults cannot be attributed to the stronger repetition priming (much shorter response latencies after identity than after unrelated primes) because larger repetition priming is actually observed in the group of younger adults (57ms vs. 48ms). Larger magnitude of identity priming produced by younger adults may possibly show their greater sensitivity to the condition which yields the maximum amount of facilitation.

Taken together, the obtained results indicate no signs of cognitive decline in older age. Instead, the results may indicate some advantage for older adults as shown by the similar amount of facilitation after identity and derived primes in the group of older speakers in contrast to the group of younger speakers. This finding could possibly be interpreted as being due to the lifelong experience of older adults and stronger memory links between related forms. However, this explanation lacks further evidence due to the similar facilitation effects in both age groups after related primes relatively to unrelated primes. Instead, older adults show evidence of age-related slowing as shown by much slower response latencies. At the same time, the slower RTs in the older group do not cooccur with significantly higher accuracy which runs against the assumptions of the “speed-accuracy trade off” predicted by Ramscar, Hendrix, Shaoul, Milin, and Baayen (2014). Whether these patterns are generally reliable or apply only to the derived -ost’ nouns would be further examined in the next chapter on processing of inflected forms in Russian.

2.3.5 Experiment II. Inflection.

2.3.5.1 Design and predictions.

The masked priming experiment on processing of inflected verbal forms with and without stem allomorphy in Russian is based on the auditory priming experiment conducted by Gor and Jackson (2013). The experiment conducted as part of the current PhD project differs from the original study reported by Gor and Jackson (2013) in following ways.

First, while the study by Gor and Jackson (2013) did not have an identity condition, the present study included it to keep the design parallel to all other experiments conducted as part of the PhD thesis. Moreover, this condition is also useful as it serves as a baseline showing the maximum amount of facilitation and, hence, might allow us to observe the differences in facilitation effects which might be otherwise not revealed only by comparing related and unrelated conditions as it was done in the original study.

Secondly, whereas the experiment by Gor and Jackson (2013) included related items which belonged to two lemma frequency ranges, that is high-frequency and low-frequency items, only high-frequency items were incorporated into the present experiment. This was done as the inclusion of the identity condition has doubled the number of related items in the experiment. Consequently this was compensated for by the large quantity of new filler items to keep the ratio of related items as low as possible leading to the total number of stimuli in the experiment of more than 400 (for the details refer to the following paragraphs). Including yet another set of experimental items (from the low-frequency range) combined with the required number of the unrelated filler items would have made the whole experiment unacceptably long and tiresome especially for older adults. Thus, it was decided to leave only the items from one frequency range, that is high-frequency items, which would also be parallel to other experiments included into the present Ph.D. thesis which lack division into frequency ranges and tend to include mostly high-frequency experimental items.

Third, due to the inclusion of the third condition in addition to the related and unrelated ones, we slightly increased the number of items in each experimental set from 20 to 21 for -aj verbs, -i verbs and idiosyncratic verbs (42 in total for the two latter groups) as well as semantically and orthographically related items. Moreover, some of the items in the items in all original sets (except for -aj set) of 20 prime-target pairs were changed to improve the matching. Thus, in the set of -i as well as idiosyncratic verbs one target and three unrelated primes were changed. In the set of semantically related items, 4 unrelated primes were changed, in the set of orthographically related items two targets were changed.

One of the reasons to change the original items was, for instance, the chosen experimental paradigm. Some primes in the original study, for example, *plaču* are homographs and could be the forms of two different verbs such as *platit'* ('to pay') or *plakat'* ('to whine'). Gor and Jackson (2013) used an auditory priming paradigm which allowed them to differentiate between two forms as the stress is realized on the ultimate syllable if *plaču* is a form of *platit'* ('to pay') or the first syllable if it is a form of *plakat'* ('to whine'). In our design this is not possible and thus such forms had to be avoided.

Due to the changes described above, all the matching values provided below were calculated and differ from the ones reported by Gor and Jackson (2013).

The original design included three item groups: a morphological, a semantic and an orthographic one. Three types of verbs were used in the morphological set, which, as the authors note, mirror regular, semi-regular and irregular categories of Spanish verbs examined in a study of Spanish-Catalan bilinguals (de Diego Balaguer, Sebastián-Gallés, Díaz, & Rodríguez-Fornells, 2005).

The sets of morphologically related items consisted of 21 target verbs in each group (e.g., *tratit'* 'spend') preceded either by the related (e.g., *traču'* 'I spend'), an identity prime or a matched unrelated control prime word (e.g., *spešu* 'I hasten'). In the unrelated condition the primes were semantically and orthographically unrelated to the target verbs. All targets were infinitives, whereas all primes were in the first person singular, non-past tense. All verbs we used were unprefixed and imperfectives.

The properties of the verb classes (presented separately in the original study by Gor and Jackson (2013)) are provided in Table 6.

Table 6

Morphological Properties of Verb Stems Included in the Experiment

Verb types	Prime	Target	Non-automatic morphological processes
-aj	rabot-aj+u → *rabotaju*	rabot-a(ɉ)t' → *rabotat'* automatic consonant truncation	No
-i	ko[s→u](ɨ)+u → *košu* automatic vowel truncation consonant mutation	*kosit'*	Yes
Idiosyncratic verbs	moj+u → *moju*	m[o→y](ɉ)+t' → *myt'* automatic consonant truncation vowel alternation	Yes
	klad+u → *kladu*	kla(đ)+st' → *klast'* automatic consonant truncation special infinitive	Yes

Note. Adapted from "Morphological decomposition and lexical access in a native and second language: A nesting doll effect" by K. Gor and S. Jackson, 2013, *Language and Cognitive Processes*, *28*(7), p. 1072. Copyright 2013 by Taylor and Francis.

As noted by Gor and Jackson (2013) there is only a very limited number of "irregular" (in our study mostly referred to as "idiosyncratic") verbs in Russian which made matching for frequency, length in letters and syllables across three sets of morphologically related verbs extremely problematic. These values were nonetheless still balanced as much as possible. Frequency, mean number of syllables and letters are provided in Table 7.

Table 7

Length and Frequency Information for Five Item Sets in Experiment on Processing of Inflected Word Forms in Russian

	-aj	-i	Idiosyncr.	Orthographic	Semantic
Target lemma frequency	57.46	62.12	90.67	102.25	93
Length of targets (letters)	6.8	7	4.8	5.09	5.3
Length of targets (syllables)	2.09	2.09	1.6	1.76	2.14
Length of primes (letters)	5.7	5.04	3.6	5.57	5.76
Length of primes (syllables)	3.09	2.09	1.3	1.8	2.3

Due to their morphological properties, infinitives in the idiosyncratic group are on average shorter in syllables as well as letters than infinitives of -aj verbs (syllables: t(33)= 6.13, p < .001; letters: t(40)= 7.32, p < .001) and -i verbs (syllables: t(33)= 6.13, p < .001, letters: t(40)= 8.21, p< .001). The length of the infinitives of the *-aj* and *-i* class verbs was matched in terms of the syllable length (t(40)= 0, p = 1) as well as number of letters (t(40)= -0.72, p = 2.02).

Owing to the fact, that in 1P.Sg. forms only -aj verbs have one more syllable than infinitives matching across sets of related primes is hardly possible, such that -aj primes have more syllables than -i primes (t(40)= 10.7, p< .001) and -i primes are in turn longer than related primes of idiosyncratic verbs (t(30)= 3.01, p< .006). As a consequence of such morphological properties, the same pattern emerges for the length of related primes calculated in letters so that -aj prime verbs are longer than -i verbs (t(37)= 2.36, p= .023) and -i primes are longer than related primes in the idiosyncratic set (t(39)= 4.61, p< .001).

However, as noted by Gor and Jackson (2013) the comparison for primes across conditions within a given set might be more important, since only primes differ across priming conditions. For the most relevant comparison between related and unrelated primes the only found difference indicates that unrelated primes are longer than related primes for the idiosyncratic set in the number of letters (t(37)= 3.13, p= .003).

Whereas matching for length was highly complicated due to the complex morphological properties of the examined verb classes, one-way ANOVA comparison has shown that the lemma frequency of all three classes is indeed comparable (F(2,60)= 1.58, *p*= .21). Moreover, the differences in lemma frequency of related and unrelated primes within the prime sets the lemma frequency were not significant (all *p*s > .7).

For the same reasons, as in the study on derivation, this experiment also included two control sets of items which were either semantically or morphologically related in order to check the nature of possible priming effect in the sets of morphologically related items. Each group included 21 target verbs. The semantically related items were chosen based on the pretest with native speakers or Russian.

Similarly to the study on derivation, orthographic relatedness in the pairs of orthographically related primes and targets was designed to mirror the overlap between morphologically related pairs using Match Calculator by Colin Davis (http://www.pc.rhul.ac.uk/staff/c.davis/Utilities/MatchCalc/). The mean overlap for related primes and targets for -aj verbs was 0.69 (SD= 0.03), for -i verbs was 0.43 (SD= 0.1) and for irregular verbs was 0.31 (SD= 0.14). For the orthographically related items the mean overlap was designed to match the degree of overlap between related -aj primes and targets and was equal to 0.67 (SD = 0.13). The overlap was also calculated using the SOLAR model, which takes into account the position of identical letters in the two words.

These estimates were compared using Welch t-test and they did not differ in the two item sets with the highest overlap (-aj verbs and orthographically related items), neither for the absolute overlap (t(22)= .7, *p*= .48) nor for the overlap score calculated based on the SOLAR model (t(23)= .65, *p*= .52).

As indicated by the one-way ANOVA comparison, the lemma frequency of all targets for all five sets of items does not significantly differ (F(4,104)= 1.97, *p*= .1). Target items in two control sets were also of comparable syllable length to target -aj and -i verbs (F(3,80)= 2.16, *p*= .09). Within sets of orthographically and semantically related items, related and unrelated primes were of similar syllable length (all *p*s > .15) and of comparable lemma frequency (all *p*s>. 19).

Thus, despite some difficulties with matching due to the morphological properties of the examined items, it can be concluded that materials are balanced and are not expected to influence the critical effects.

Experimental items were distributed across three presentation lists according to the Latin Square Design so that each list had only one out of three prime/target pairs from each of the three experimental sets.

105 critical items were mixed with 315 fillers, making it 420 items in the whole experiment (see Appendix B for the list of all critical items). Half of the targets, as well as half of the primes were existing words, and another half were nonwords constructed by changing one or two letters of an existing Russian word. 55% of all targets were verbs with remaining 45% being nouns and adjectives. Proportion was the same for filler items. Nouns and adjectives that were used as filler words were in their dictionary forms: nouns in Nominative Singular (or Plural, if they had no Singular form), adjectives in Nominative Singular masculine form. Verbal fillers were either also in their dictionary form, that is infinitives, or in in the first person singular, non-past tense similar to related and unrelated primes in three sets of morphologically related items. In order to compensate for the fatigue effects, each of the three lists was presented in the reverse order approximately for the half of the participants. The ratio of related experimental prime-target pairs was around 16%.

Based on the previous research on morphological processing and ageing several outcomes could be expected:

1) Similar facilitation effects for -aj verbs and other verbs which would indicate that properties of the stem (with and without allomorphy) do not affect processing at the stage of the access representations similarly to more central representations (Gor & Jackson, 2013; Reid & Marslen-Wilson, 2002)

2) Alternatively, more facilitation effects for -aj verbs which could reflect decomposition of the -aj stems into the root + affix in contrast to the storage of the allomorphic stems (e.g., similar to assumptions for verbs in Spanish (Rodriguez-Fornells et al., 2002))

3) Less facilitation for allomorphic stems with advancing age which could indicate a possible age-related decline of the declarative memory and weaker memory links (Clahsen & Reifegerste, 2017)

4) Alternatively, more facilitation for allomorphic stems with advancing age which could indicate the effects of greater (lifelong) experience facilitating storage-based access (Reifegerste et al., 2017)

5) Higher accuracy and slower response latencies in older adults indicating speed-accuracy trade-off as predicted by Ramscar et al. (2014)

2.3.6 Experiment II. Analysis.

2.3.6.1 ***Data analysis***.

We applied the same data cleaning procedures as in our study on derivation. Moreover, we have also removed from our analysis participants who were excluded in the previous study based on the same criteria and also to maintain consistency. No further participants were excluded.

Additional data cleaning included elimination of all incorrect responses and timeouts (3.21% for the group of older adults and 3.34% for the group of younger adults). Similarly to our study on derivation, we conducted analyses based on the transformed RTs (inverse transformation) and applied cutoff points to remove extreme values which were higher or lower than 2 SD from the mean RT per participant in order to normalize the distribution. As a result, additional 4.67% of the remaining data for the older group, and 4.95% of the data points for the control group of younger adults were removed.

We analyzed RTs with mixed-effects linear regression models with crossed random effects for participants and items (see Baayen, Davidson, and Bates (2008)) using the languageR package (Baayen, 2008) and the lme4 package (Bates et al., 2014).

The model included two fixed effects Prime Sets (Morphological, Semantic, Orthographic) and Condition (Unrelated, Related, Identity) and their interaction. As predictors models included Trial Number (the position of the item in the presentation list; centered) to control for trial-level task effects, such as fatigue, Reaction Time on the Previous Item (inverse transformed, centered), Lemma frequency (centered) and Length, that is number of letters (centered).

2.3.6.2 Results.

Table 8 on the next page illustrates mean accuracy rates, by-participant RT means, as well as standard deviations of RT data in each condition for groups of older and younger adults.

Table 8

Mean RTs, Standard Deviations and Mean Accuracy for Four Item Sets by Condition for Older and Younger Adults

		Older adults			Younger adults		
		Identity	Related	Unrelated	Identity	Related	Unrelated
-aj verbs	RT	679.1	685.5	726.8	583.5	590.8	615.5
	SD	129	125.7	130.6	121.3	127.2	118.4
	Accuracy (%)	96.9	95.1	92.4	95.5	93.1	91.8
Allomorphic verbs	RT	669.3	715.5	727.9	579	604.4	631
	SD	120.8	141.8	127.8	118	122.2	124
	Accuracy (%)	90.8	88.1	84.3	92.2	86.9	84.8
Semantic	RT	643.5	703.9	714.7	545.4	585.1	610.9
	SD	110.3	126.9	129.2	123	99	113.6
	Accuracy (%)	97.3	93.8	95.1	98	97.1	94.3
Orthographic	RT	646.8	688.2	703.9	536.9	600.8	598
	SD	133.5	127.4	122.3	107.8	124	106.4
	Accuracy (%)	97.3	94.6	94.6	94.7	93.5	91.8

As mentioned in the previous chapter on processing of derived forms, our main interest was to analyze data on morphological processing of inflected forms by older adults. The accuracy analysis for the group of older adults revealed significantly more accurate responses after related primes than after unrelated primes (β= -0.452, SD= 0.22, z-value= -2.002, p= .045) in the group of stem-change verbs. For the -aj verbs with no stem changes no such facilitation was found ($p > .23$).

In neither group of morphologically related primes presentation of identity primes elicited significantly more accurate responses than presentation of related primes (all *p*s > .14). No significant interaction between Type (allomorphic verbs vs. -aj verbs) and Condition was found (all *p*s> 0.82). Furthermore, no differences between experimental conditions were found in the sets of orthographically and semantically related primes and targets (all *p*s> .09).

To examine response patterns in processing of inflected forms with and without allomorphy in more detail we fitted a mixed-model effect to the latency data of older adults. The reference levels for Prime Types (-aj verbs and stem change verbs) were adjusted accordingly so that all RT patterns could be investigated in one model. See Table 9 for the model.

Table 9

The Best-fit Model for the RT Data from two Morphological Sets for the Older Participants in the Study on Inflection in Russian

Random effects		Variance	Std.Dev.	Correlation	
Item	Intercept	0.0035388	0.05949		
ID	Intercept	0.0259100	0.16097		
	Condition [unrel – rel]	0.0004215	0.02053	-0.79	
	Condition [ident – rel]	0.0015186	0.03897	0.13	0.50
Residual		0.0342900	0.18518		

Fixed effects:	Estimate	Std. Error	t value
Lemma frequency	-0.0003221	0.0001341	-2.40
Trial number	-0.0001111	0.0000387	-2.87
Length	0.0204997	0.0072234	2.84
RT on previous item	0.0833113	0.0200507	4.16
Relevelled for -aj verbs:			
Condition [unrel – rel]	0.0906525	0.0184684	4.91
Condition [ident – rel]	-0.0125627	0.0191654	-0.66
Relevelled for stem-change verbs:			
Condition [unrel – rel]	0.0459191	0.0138567	3.31
Condition [ident – rel]	-0.0879085	0.0148309	-5.93
Effect of Set on RT [for related condition]			

Prime Type [allomorph – -aj]	-0.0839103	0.0233765	-3.59
Interaction of Condition and Prime Set			
Prime Type [allomorph – -aj]: Condition [unrel – rel]	0.0447334	0.0225090	1.99
Prime Type [allomorph – -aj]: Condition [ident – rel]	0.0753458	0.0221880	3.40

For the older group, related -aj primes elicited significantly faster responses than unrelated primes (t= 4.96). Moreover, response latencies after related primes were as fast as after identity primes for -aj verbs (t= -0.66). This pattern indicates high efficiency of the related forms as primes which facilitate recognition of the target form to the same degree as the identical prime.

The output of the model also shows that related primes from verbs with stem change produced faster RT's to the targets compared to unrelated primes (t= 3.31) and much slower RT's in comparison to identity primes (t= -5.93). Moreover, an interaction suggests differences in priming effects (unrelated vs. related conditions) between regular -aj verbs with no stem changes and verbs with stem allomorphy (t= 1.99). Thus, this is another indication of the reduced facilitation observed for verbs with stem changes compared to -aj verbs which is in line with our hypothesis that properties of the stem should affect processing such that stems without allomorphy (-aj stems) should yield more facilitation than stems with allomorphic changes.

As, however, the initial design of the study assumes the separate treatment of several types of stem-change verbs, the group was split into two subgroups. The one subtype included -i verbs with predictable stem-changes and the other subtype included verbs with unpredictable stem-changes from various minor classes. The statistical analysis has shown no significant interaction between the two, that is between Prime Type (-i verbs vs. idiosyncratic) and Condition (related vs. unrelated, related vs. identity) indicating that both groups show similar patterns and do not differ with respect to the magnitude of facilitation (all *t*s < 1).

The facilitation effect for orthographic and semantic sets were also investigated separately by fitting mixed-effects models to the older adults' data. The models for each set included an interaction with -aj verbs and a group of verbs with stem changes in order to find out whether the facilitation effect reported previously for these verbs is morphological or whether its source might rather be due to orthographic similarities between related primes and targets or semantic relatedness.

Table 10 below presents the output of the model for the Semantic set.

Table 10

The Best-fit Model for the RT Data from the Semantic Set for the Older Participants in the Study on Inflection in Russian

Random effects		Variance	Std.Dev.
Item	Intercept	0.003868	0.06219
ID	Intercept	0.024707	0.15719
	Residual	0.033183	0.18216
Fixed effects:	**Estimate**	**Std. Error**	**t value**
Lemma frequency	-0.0002360	0.0001224	-1.93
Trial number	-0.0001171	0.00003145	-3.73
Length	0.02315	0.005992	3.86
RT on previous item	0.08061	0.01720	4.69
Facilitation effect:			
Condition [unrel – rel]	0.02311	0.01774	1.30
Condition [ident – rel]	-0.1358	0.01763	-7.70
Effect of Prime Type on RT [for related condition]			
Prime Type [allomorph – seman]	0.002630	0.02318	0.11
Prime Type [-aj – seman]	0.08186	0.02783	-2.94
Interaction of Condition and Prime Type			
Prime Type [-aj – seman]: Condition [unrel – rel]	0.06751	0.02513	2.69
Prime Type [-aj – seman]: Condition [ident – rel]	0.1230	0.02490	4.94
Prime Type [allomorph – seman]: Condition [unrel – rel]	0.02333	0.02208	1.06
Prime Type [allomorph – seman]: Condition [ident – rel]	0.04778	0.02185	2.19

The coefficients from the model indicate that responses after the presentation of the semantically related primes are not significantly faster than following unrelated primes (t=1.30) but are slower than after identity primes (t= -7.70). Thus, presentation of semantically related primes did not elicit any facilitation effect in contrast to patterns observed for -aj verbs without any stem changes and verbs with stem changes.

This difference is further confirmed by significant interactions with -aj verbs in all experimental conditions (t= 2.69 for related vs. unrelated conditions and t= 4.94 for identity vs. related conditions). For verbs with stem changes the difference in the magnitude of facilitation does not reach significance (t= 1.06), even though facilitation effect is significant for allomorphic verbs and is not significant for semantically related primes and targets.

The data from the orthographic set also helps to understand the observed patterns of results. See Table 11 below for the Orthographic set.

Table 11

The Best-fit Model for the RT Data from the Orthographic Set for the Older Participants in the Study on Inflection in Russian

Random effects		Variance	Std.Dev.
Item	Intercept	0.003943	0.0628
ID	Intercept	0.026245	0.1620
	Residual	0.034662	0.1862

Fixed effects:	Estimate	Std. Error	t value
Lemma frequency	-0.0003038	0.0001194	-2.54
Trial number	-0.0001009	0.00003304	-3.05
Length	0.01719	0.006518	2.64
RT on previous item	0.07071	0.01715	4.12
Facilitation effect:			
Condition [unrel – rel]	0.04232	0.01809	2.34
Condition [ident – rel]	-0.109	0.01798	-6.06
Effect of Prime Type on RT [for related condition]			
Prime Type [allomorph – orthog]	0.02772	0.02398	1.16
Prime Type [-aj – orthog]	-0.05388	0.02915	-1.85
Interaction of Condition and Prime Type			

Prime Type [-aj – orthog]: Condition [unrel – rel]	0.04847	0.02566	1.89
Prime Type [-aj – orthog]: Condition [ident – rel]	0.09648	0.02543	3.79
Prime Type [allomorph – orthog]: Condition [unrel – rel]	0.003695	0.02254	0.16
Prime Type [allomorph – orthog]: Condition [ident – rel]	0.02024	0.0223	0.91

In the set of orthographically overlapping items the results indicate a facilitation effect, as responses to targets following unrelated primes are significantly slower than after related items (t= 2.34). Responses after related primes are in their turn, however, slower than following identity items (t= 4.12).

This pattern could also mean that a facilitation effect in -aj and stem-change verbs could be explained through the orthographic overlap of presented primes and targets. This is especially true in the case of the verbs with stem change as we found no significant interaction between orthographically overlapping items and allomorphic verbs (t= 0.16) which shows an identical magnitude of the facilitation effects in both sets.

Whereas the absence of the interaction between verbs with stem changes and semantically related items might be of less importance due to dissimilar priming patterns (i.e. due to the lack of the facilitation in semantically related items), its absence in case of orthographically related and stem-change verbs could indicate that amount of facilitation in orthographically overlapping and allomorphic verbs is identical.

Importantly, an interaction effect between -aj verbs and orthographically related pairs almost reaches significance when comparing the amount of priming effects (t= 1.89 which amounts to p= 0.06). An interaction between identity and related conditions for these sets is also highly significant (t= 3.79). In other words, this indicates that a facilitation effect found for -aj verbs is larger than for purely orthographically related pairs which is a further crucial evidence indicating its morphological nature.

Thus, a priming effect found for -aj verbs is different from the facilitation (or absence thereof) found in control sets of purely semantically and orthographically related items. Furthermore, it is significantly larger and more robust than a facilitation elicited by verbs with stem changes measured as a difference in response latencies between related and unrelated conditions.

Additionally, while related -aj forms primed targets almost as effectively as identity primes, related stem-change verbs primed target forms significantly less effectively than identity primes. Moreover, magnitudes of facilitation effects in orthographically and stem-change verbs (unlike -aj verbs) do not statistically differ which could mean that priming effects observed in allomorphic verbs are due to simple orthographic rather than morphological relatedness.

The results in our experiment summarized above indicate a clear dichotomy between verbs with stem changes and verbs without stem-changes (-aj verbs). The robust priming effects found for verbs without stem changes might indicate their fully combinatorial nature in line with our predictions in contrast to allomorphic stems which appear to be lexically stored and thus yield much less facilitation. This dichotomy might be taken to illustrate the two-way contrast between rule-based computations and lexical storage which is assumed by some linguistic theories including the dual-route model. In this case the nature of the allomorphy itself (e.g., whether alternations are idiosyncratic or more predictable) should not significantly affect the processing mechanism which is supported by our results (i.e., no difference between -i stems with predictable allomorphic changes and a set of verbs with idiosyncratic changes). However, until now our conclusions are limited to the group of older adults only.

2.3.6.2.1 Between-group comparisons.

To investigate whether accuracy patterns found in the group of older adults differed from patterns found in the control group of younger adults the best-fit generalized linear model which included Prime Set (-aj verbs, stem-change verbs), Condition (identity, related, unrelated), Group (old / young) and three-way interaction was compared to a minimally different model with three two-way interactions. The comparison of two models revealed that inclusion of interaction does not improve the model fit ($\chi^2(2)= 4.88$, $p= .773$) showing no differences across two groups in the morphological set.

The same omnibus model revealed that across all conditions and sets main effect of Age Group is not statistically significant (β= -0.148, SD= 0.154, z-value= -0.963, p= .335) showing no evidence of higher accuracy of the older adults compared to younger adults[11]. To additionally examine the accuracy rates in the two age groups we compared the accuracy rates only for the unrelated condition. This comparison also has not found any indication that accuracy rates tends to grow with advancing age (β= -0.163, SD= 0.18, z-value= -0.905, p= .365).

[11] The same is true if the omnibus model includes orthographic and semantic sets with (β= -0.089, SD= 0.513, z-value= -0.692, p= .488) also showing no overall difference in accuracy between older and younger adults

In order to examine RT data in more detail the best-fit generalized linear model which included Prime Set (-aj verbs, stem-change verbs), Condition (identity, related, unrelated), Group (old / young) and a three-way interaction was compared to a minimally different model with three two-way interactions similarly to the accuracy data. The interaction term has not improved the model fit ($\chi^2(2)= .797$, $p= .671$) indicating similarities between two groups.

The omnibus model demonstrated robust effect of slowing of older adults compared to younger adults, as response latencies averaged across all conditions as well as two morphological sets increase with advancing age (β= -0.2320, SD= 0.04259, t= -5.45).[12] This effect was also present when comparisons were conducted exclusively for the unrelated condition (β= -0.2282, SD= 0.03948, t= -5.78).

Even though priming effects appear to be similar for the two groups, we fitted additional models to examine separately priming effects -aj verbs and verbs with stem changes to the data of the control group of younger adults. Fitting additional models would allow to assess more precisely facilitation effects for the group of younger adults, considering existence of large group differences between groups of older and younger adults (e.g., in terms of overall speed of RT), as well as to directly compare priming effects.

The Table 12 on the next page presents the output of the model on -aj verbs with the group of younger adults as a reference level.

[12] The main effect of Age Group remains statistically significant if the omnibus model also includes orthographic and semantic sets (β= -2.408e-01, SD= 4.140e-02, t= -5.82).

Table 12

The Best-fit Model for the RT Data from the Set of -aj Verbs in the Study on Inflection in Russian (with a Group of Younger Adults as a Reference Level)

Random effects		Variance	Std.Dev.
ID	Intercept	0.029272	0.17109
ItemID	Intercept	0.001805	0.04249
	Residual	0.047795	0.21862
Random effects	Estimate	SE	t-value
Lemma frequency	-0.0008268	0.0003023	-2.74
Trial number	-0.0001198	0.00005702	-2.10
Length	0.05140	0.01383	3.72
RT on previous item	0.1328	0.02454	5.41
Facilitation effect:			
Condition [unrel – rel]	0.08365	0.02062	4.06
Condition [ident – rel]	-0.02053	0.02041	-1.01
Main Effect of Age			
Age [Young – Old]	0.2309	0.04393	5.26
Interaction of Condition and Group			
Group [Old – Young]: Condition [unrel – rel]	0.006264	0.02969	0.21
Group [Old – Young]: Condition [ident – rel]	0.008334	0.02936	0.28

For the regular -aj verbs in the control group of younger adults results indicate that presentation of related primes led to faster response latencies compared to RTs following unrelated primes (t= 4.06). Moreover, related -aj verbs primed targets as efficiently as identity primes (t= -1.01), producing a full priming effect.

This is, however not the case for the verbs with stem allomorphy as follows from Table 13 which demonstrates that reaction time latencies following related primes are significantly slower than after identity primes (t= -5.37). However, the difference in response latencies between related and unrelated primes is also significant (t=4.79), showing a significant facilitatory effect of related compared to unrelated primes in the group of younger adults.

Table 13

The Best-fit Model for the RT Data from the Set of Verbs with Stem Allomorphy in the Study on Inflection in Russian (with a Group of Younger Adults as a Reference Level)

Random effects		Variance	Std.Dev.
ID	Intercept	0.028385	0.16848
ItemID	Intercept	0.005663	0.07525
	Residual	0.045013	0.21216
Random effects	**Estimate**	**SE**	**t-value**
Lemma frequency	-0.0002766	0.000148	-1.87
Trial number	-0.00002376	0.0000372	-0.64
Length	0.01353	0.007541	1.79
RT on previous item	0.1186	0.01762	6.73
Facilitation effect:			
Condition [unrel – rel]	0.07029	0.01467	4.79
Condition [ident – rel]	-0.07726	0.01438	-5.37
Main Effect of Age			
Age [Young – Old]	0.2252	0.04231	5.32
Interaction of Condition and Group			
Group [Old – Young]: Condition [unrel – rel]	-0.02473	0.0212	-1.17
Group [Old –Young]: Condition [ident – rel]	-0.01264	0.02079	-0.61

These patterns are in line with the results of comparison between an omnibus model which included a three-way interaction between age group, conditions and prime set against a model which included the relevant three lower-level two-way interactions. Separate analysis reveals the presence of a facilitation effect for all types of morphologically related primes and targets for the younger group similar to previously reported findings for the older group and absence of interaction of Age Group (Old vs. Young) and Condition showing similar magnitudes of facilitation in both examined groups.

2.3.7 Experiment I and experiment II. Inflection versus derivation.

Up to this point we examined response patterns separately for derived and inflected words as well as for the control sets of orthographically and semantically related words in older adults. However, one important comparison due to the original design of the experiments has been left out, that is the comparison between magnitudes of priming for derived and inflected words. In what follows, we will attempt to address this question.

For both -aj verbs and verbs with stem changes it remains unclear whether facilitation effects found for these groups differ from facilitation observed for derived words. This question is of high theoretical value, considering linguistic differences between processes of derivation and inflection which are often observed in experimental studies testing groups of participants to some extent disadvantaged with regard to the available processing mechanisms such as L2 speakers (Jacob et al., 2017; Kırkıcı & Clahsen, 2013). For instance, the study by Jacob et al. (2017) found similar priming effects for derived words and regularly inflected forms for native speakers of German. Non-native speakers of German, however, have shown a priming effect only for derived words. The question is whether the similar contrast between inflection and derivation could be also observed in the group of older adults.

We ran an analysis on the combined set of data from older adults including derived words, -aj verbs and verbs with stem changes. This was possible, as these two studies were conducted on the same group of participants and even during the same testing session. Moreover, the procedure, such as SOA, length of presentation of targets etc. was identical in both studies. In order to statistically control for differences between derived and inflected items in terms of their length and frequency, all fitted models included predictors such as Lemma frequency (centered) and Length (number of letters; centered) in addition to Trial Number (the position of the item in the presentation list; centered) to control for trial-level task effects and Reaction time on the Previous Item (inverse transformed; centered).

We fitted a mixed-model to the combined latency data from older adults. This model showed no interaction between derived words and -aj verbs and Condition (related vs. unrelated: β= -0.009148, SD= 0.02432, t= -0.38; related vs. identity: β= 0.001528, SD= 0.02405, t= 0.06). However, interaction between derived and allomorphic verbs was significant for all conditions (related vs. unrelated: β= -0.0562, SD= 0.02086, t= -2.69; related vs. identity: β= -0.07523, SD= 0.02059, t= -3.65).

This pattern indicates that facilitation effects found for derived words and -aj verbs with no stem allomorphy are of similar size and statistically do not differ, whereas the facilitation effect for derived words is stronger than for verbs with stem changes in older adults. Combined with findings in 2.3.6 Experiment II. Analysis establishing a stronger priming for -aj verbs than for verbs with stem changes, facilitation for -aj inflected forms and derived words in older adults appears to be similar. Moreover, they also appear to be truly morphological in nature as for both -aj inflected forms and derived words magnitude of facilitation effects is higher than for only orthographically or semantically related primes and targets. These findings will be further reviewed in the next chapter 2.3.8 Discussion.

2.3.8 Discussion.

To summarize, we found a robust priming effect for -aj verbs with no stem allomorphy and derived -ost' nouns in the group of older adults and less facilitation for verbs with stem allomorphy At the same time, results show similarity between observed patterns for -i verbs with rule-based stem allomorphy and verbs with idiosyncratic stem changes in the group of the older adults, as indicated by absence of interaction between two sets. In contrast to this pattern, we found a statistically significant interaction between -aj verbs with no stem changes and verbs with stem changes in all experimental conditions. Moreover, facilitation effects observed for verbs with stem changes are not statistically distinguishable from the orthographic priming. This could be ascribed to orthographic overlap between related primes and targets.

We also considered this possibility for the derived -ost' nouns. Crucially, we observed a robust priming effect (no difference between identity and related condition but a large difference between related and unrelated conditions) and this facilitation effect (a difference between related and unrelated conditions) was statistically different from response patterns in the orthographic and semantic sets.

The similarity in priming effects between -aj verbs with no stem allomorphy and derived -ost' words was further examined in a combined analysis. The analysis revealed a similar magnitude of priming for -aj verbs and derived -ost' nouns.

Since we are mostly interested in the effects of ageing we focused mainly on the analysis of RT patterns observed in the data from the older adults. As shown by the analyses of the omnibus models which included data from younger adults, the results are generally parallel to the results from the older adults.

Crucially, however, we found a main effect of age in each set showing that response latencies of older adults were substantially slower than response latencies of younger adults. This could be possibly interpreted as indicating the effect of the so called general slowing which is often associated with ageing. At the same time, we found no indication that with advancing age accuracy rates tend to increase. In all examined sets accuracy rates of older and younger adults do not statistically differ.

These findings allow us to argue against a claim of speed-accuracy tradeoff as assumed, for example, by Ramscar et al. (2014). Instead, they indicate a global effect of slowing in older adults which does not necessarily correlate with higher accuracy in linguistic tasks whereas according to the simulation models by Ramscar et al. (2014), older speakers should have also responded not only slower but also more accurately in such tasks. In that case slower reactions time could have been interpreted not as an effect of decline but rather of lifelong learning. We found no evidence to support "a picture in which an improvement in one dimension – accuracy – is shown to come at a cost in another, speed" (Ramscar, Hendrix, Love, & Baayen, 2013, p. 36). The claim by Ramscar et al. (2013) is based on the assumption that younger speakers might have a smaller vocabulary and thus *for them* lexical decision experiments might have a higher ratio of non-words than existing words. Existing words would thus be more obvious and easier to detect. That would account for lower accuracy of younger adults as well as faster reaction times. The results of the present study show, however, only generally slower response latencies of older adults.

Overall, our findings show that processing of complex words in not significantly affected by ageing in Russian as response patterns are very similar in groups of both older and younger adults. The only robust difference consists in the generally slower responses in the group of older adults.

In addition to the effects of ageing, another goal of these experiments was to investigate the processing mechanisms of derived words, inflected words and the role of stem allomorphy. We will discuss these mechanisms in greater detail in what follows below referring to the results produced by older speakers.

This study found robust and stable differences in priming effects between -aj verbs without stem allomorphy on the one hand and verbs with stem allomorphy on the other hand. These differences consist in the observed priming effects (full vs. partial) found for both age groups, in magnitudes of priming (larger priming of -aj verbs as compared to allomorphic verbs) and possibly the nature of the priming effect (at least for the older group).

The observed dichotomy between the -aj class and other verbs in our study resembles the findings from Spanish and many other Romance languages. In this case, the dichotomy could be viewed as supporting assumptions of the dual-route model which would expect differences between forms which are decomposed and thus directly activate their base forms and lexically stored forms, for example, stems which are not decomposed and, hence, produce only indirect activation of the base forms. This explanation was proposed, for example, by Rodriguez-Fornells, Münte, and Clahsen (2002) to account for the ERP data in Spanish.

Notably, inflectional endings in Russian are regular regardless of the verb. This was the reason for Clahsen (2016) to criticize an overly simplistic distinction between regular and irregular forms applied to languages other than English. Instead, it would be more reasonable to take into account other factors such as stem formation mechanisms and differences between what could be considered marked and unmarked stems. Crucially, the nature of the stems in the experiment differed such that -aj verbs had the same stems in both items (*rabotaju –rabotat'* 'to work'), -i verbs contained a predictable alternation (*xožu – xodit'* 'to walk'), and the verbs containing unpredictable alternations (*kladu – klast'* 'to put'). Apparently, the presence of stem allomorphy influenced morphological processing, such that for -aj verbs with no alternation full priming effects indicating full decomposition (possibly down to the root) was found. In contrast for verbs with an alternation only a partial priming indicating indirect access was observed. This could be an indication of such forms being stored as subentries to the base forms. Note, however, that this interpretation is still not identical to the dual-route model as it focuses on properties of the stems and not of the inflectional endings as such.

Interestingly, the type of the stem allomorphy did not seem to play a role as -i verbs with stem changes which could be predicted from the morphophonological rules of contemporary Russian and verbs with idiosyncratic changes which are not predictable from such rules pattern together. This finding is even more striking considering other differences, for example, in productivity and type frequency between two groups included into the study. Apparently these factors do not significantly influence the processing of the inflected forms at least at the level of access representations in contrast to the opposition between allomorphic and combinatorial stems in line with the general distinction between rule-base and lexically stored forms made by the dual-route models.

The results of the present masked priming experiment contradict the findings from the auditory priming by Gor and Jackson (2013) who found equal priming patterns for all groups of verbs and not only for verbs with stem changes as in the present study. There are, however, several reasons to treat the findings by Gor and Jackson (2013) with caution and not to draw strong conclusions from the direct comparison.

Firstly, the study by Gor and Jackson (2013) only included 11 native speakers of Russian as a control group. Thus, with less than 100 observations for some conditions and rather large standard deviation (which is in some cases higher for native speakers than for non-native speakers) its reliability could be questioned. Secondly, as the authors have not included an identity condition, the possibility that verbs with and without allomorphy differ with regard to the identity priming cannot be disregarded as it is indeed the case in our study with -aj primes with no stem allomorphy being as effective as identity primes in contrast to verbs with stem changes with related primes producing much less facilitation than identity primes.

Thirdly, even though the authors have included phonological and semantic control conditions, the results for these sets were, unfortunately, not reported. Considering overt presentation of primes as well as targets, so that participants were consciously aware of the primes influence of semantic relatedness, for instance, could not be safely excluded.

Finally, even if one assumes the morphological nature of the reported effects it is still possible to interpret these effects as being modality-specific. The auditory presentation of primes used by Gor and Jackson (2013) differs from the visual one in many ways. These may include differences between processing stages tapped into by two methods as well as more difficulties in detecting affixes due to them being less salient in spoken language (Aronoff et al., 2016) or as mentioned in the footnote by Gor, Chrabaszcz, and Cook (2017) due to the fact that that auditory signals are processed in a linear way, that is as they unfold in time, whereas for visual processing the whole word is immediately available. The combination of these differences between two methods could potentially account for the differences in results. Imagine, for example, that difficulties in detecting inflectional affixes could have increased the reliance on semantic relatedness between primes and targets in the auditory priming leading to similar patterns for all types of verbs.

From a cross-linguistic perspective our results could be compared to findings from another Slavic language with a similar verb system, namely Polish, obtained by Reid and Marslen-Wilson (2002). The notion of regularity was applied by the authors to the stems and, hence, the distinction between regular and irregular verbs was defined by the properties of the alternation in the stem, which could be derived by the phonological rules or arises in certain morphophonological contexts for regular verbs, while its occurrence cannot be predicted for irregular verbs. Thus, the authors included three types of verbs into their experiments: verbs without stem allomorphy such as *czyt-asz* 'read 2P.Sg' from *czyt-a-ć* 'to read' (cf. *čit-aj-eš – čit-a-t'* in Russian also without stem alternation), verbs with regular alternations *nosz-ę* 'carry 1P.Sg.' from *nos-i-ć'* 'to carry' (cf. *noš-u – nos-i-t'* in Russian) and verbs with irregular alternations *trz-e-ć* 'to grate' and *tr-ą* 'grate 3P.Pl' such as the vocalic alternation e : 0 (cf. *ter-e-t'* and *tr-ut* in Russian).

Reid and Marslen-Wilson (2002) conducted a delayed repetition auditory-auditory priming which included a set of semantically related items to exclude semantic effects in the previously conducted cross-modal priming experiment. The authors reported similar magnitudes of priming for all verbs and assumed that a "uniform set of processing procedures and representations are applied to Polish regular and irregular verbs" (Reid & Marslen-Wilson, 2002, p. 831).

The study by Reid and Marslen-Wilson (2002) could be criticized for not having included an identity condition which might have shown differences between classes. It is also not entirely clear what inflected forms were chosen for primes and targets since the provided examples indicate a large variability (2P.Sg. – infinitive for verbs without alternations, 1 P.Sg. – infinitives for verbs with regular alternations and infinitive – 3P. Pl for irregular verbs). It might be possible that some forms are more difficult to process (e.g., due to different frequencies of forms belonging to 1P, 2P or infinitives and markedness of such forms in general) which could have influenced the magnitude of priming.

Finally, the results from the study by Reid and Marslen-Wilson (2002) could be modality specific due to the differences in how visual and auditory signals unfold in time and are processed and might also underscore cross-linguistic differences between two languages. For instance, the authors note that alternations occur in two-thirds of words in Polish and thus are, presumably, more pervasive than in Russian. Thus, it might be possible that due to the abundance of stem allomorphy in Polish and, hence, more experience with such forms, access to stem allomorphs and mapping between prime and target stems is more automatized and efficient in Polish than in Russian. However, it is clear that sources of potential cross-linguistic differences should be experimentally tested using more comparable methods and designs.

In essence, the results of the present study indicate a dichotomy between verbs without stem allomorphy on the one hand and verbs with stem allomorphy on the other hand at least with regard to the access mechanisms. It may be argued that this interpretation is complicated by the fact that tested verbs belong to different classes and that, for example, the -aj class may have a special status and namely be the default one. Note though that the defaulthood by definition (introduced by

Clahsen (1999a) and also adopted here) is associated with the combinatorial rule-based nature of the morphologically complex words while as noted by Bybee (1996) rule-based symbol-concatenating operations are not applicable to patterns which involve stem changes. Default inflection, for example, "could be easily decomposed into stem + affix and involves affixation processes that may operate on the outputs of other morphological operations (derivation, compounding) (Clahsen, 1999a, p. 994). However, verbs belonging to non-default classes should not necessarily involve stem allomorphy in all their inflected forms.

To clarify the role of the classes *per se*, one would need to compare processing of verb forms without stem alternations belonging to different verb classes, for example, 2 P.Sg. *čit-aj-e-š* 'read 2P.Sg. Pr.t' and *nos-i-š* 'carry 2P.Sg. Pr.t' (note, though, that for -i verbs thematic vowel -i is identical to the thematic ligature -i). This comparison would make it possible to examine processing of inflected forms belonging to the supposedly default -aj and non-default -i classes which unlike the present experiment both do not involve any stem change. Thus, -i verbs could be thought of as being also combinatorial under these conditions. In this case any difference would be likely due to the class membership rather than to stem properties.

Even if one considers the influence of the verbal classes, stem alternations (presence or absence thereof) are still important properties of these classes. Along similar lines Reid and Marslen-Wilson (2002) also treated verbs in Polish based on whether they exhibit stem allomorphy or not rather than as being representative of particular classes. Importantly, it is also controversial whether the -aj class should be indeed treated as a default one. Note that studies which find support for the default status of -aj verbs, for example in production tasks, tend to rely on 1P.Sg. forms which often differ with regard to presence or absence of stem allomorphy, as the study by Kireev et al. (2015). Thus, these studies themselves could reflect the role of the stem allomorphy rather than the pure contrast between various classes.

Furthermore, from a theoretical standpoint doubts might be raised that the -aj class is a default one. Dressler (1999) already noted, for example, in Slavic languages it might be hard to establish whether there is a default class at all and claims that in Polish there are five productive classes none of which stands out as a default one. Gagarina (2002) examined the productivity of various patterns in Russian and came to the conclusion that there are less restrictions for applicability of the -i pattern in contrast to the -aj pattern. This observation is important as defaultness as "elsewhere condition" is associated with the unrestricted productivity according to the criteria laid out by Marcus et al. (1995) (Veríssimo, 2010; Veríssimo & Clahsen, 2009).

In Russian no class shows unrestricted productivity and both -aj and -i patterns could be applied to Russian nouns, proper names and to borrowed nouns and verbs according to Gagarina (2002), the -aj pattern is also applied to adjectives, sound-imitations, interjections and pronouns, while -i is chosen instead in the case of adverbs and numerals and apparently there is only restriction in case of the borrowed nous (i.e., it is not applied to borrowed nouns ending in -cija which take -ova instead). In sum, it is indeed not immediately clear which class (if at all) is a default one. Therefore, any account of our results which focuses on the properties of verb classes in Russian and defaultness of the -aj pattern rather than properties of the stem (whether they are combinatorial or allomorphic) appears to be more problematic.

The present data points towards a dichotomy between verbs without stem allomorphy on the one hand and verbs with stem allomorphy on the other hand. The results could be compared to several masked priming studies that also examined the role of stem allomorphy, for example, in processing derived words in English by McCormick et al. (2008) and inflected words in Greek by Orfanidou et al. (2011). Unlike the studies by Reid and Marslen-Wilson (2002) or Gor and Jackson (2013) where primes were overtly presented in auditory modality, the studies in English and Greek were conducted using the masked priming paradigm and tried to assess whether early stages of morphological processing are robust to orthographic alterations.

McCormick et al. (2008) examined the cases such as missing -e as in *adorable – adore* or shared -e as in *lover – love* and found robust and equivalent priming effects for what they called orthographically transparent and orthographically opaque pairs. They hypothesized that early morphological decomposition is robust to disruptive orthographic changes. They suggested that orthographic representations of the stems are underspecified, for example, for -e with facilitation effects arising due to partial stem matching the (underspecified) orthographic representation of the target word.

Orfanidou et al. (2011) explored the sensitivity of the masked as well as delayed priming to more substantial changes that in the study by McCormick et al. (2008). Critically, the researchers compared processing of primes and targets with the same stem (e.g., *theoria* 'theory' – *theoro* 'I theorize') to the condition with orthographically opaque pairs (e.g., *poto* 'drink' – *pino* 'I drink'). In both conditions primes and targets could be decomposed into stem and affix. In the latter condition, however, stems are orthographically dissimilar (*pot-/ pin-*). This type of alternation at the stem boundary is similar to the stem alternations investigated in the present study. The crucial findings is the smaller priming effect for orthographically opaque pairs in the masked priming experiment (marginally significant) and comparable magnitude in the delayed priming experiment (Orfanidou et al., 2011).

Based on the observed findings in the masked priming experiment it was concluded that early morphological decomposition "is not flexible enough to tolerate more extensive orthographic alterations" (Orfanidou et al., 2011, p. 550). The findings reported by Orfanidou et al. (2011) in the masked priming experiment are akin to the results obtained in the present study, that is the modulation of the priming effects as a result of orthographic changes in early morphological decomposition. Notably, however, our study also shows that the nature of the alternation apparently is of less importance as we found no statistical differences in priming effects between alternations that could arise only in certain morphophonological contexts and, thus are predictable and more idiosyncratic alternations.

The results from the delayed priming study by Orfanidou et al. (2011) indicate similar priming for pairs with and without stem changes. If one considers that delayed priming taps into later stages of morphological processing, it appears that morphological decomposition at this stage is semantically-informed and not orthographically-informed (Rastle & Davis, 2008). Even though Reid and Marslen-Wilson (2002) or Gor and Jackson (2013) used different methods[13] it could be claimed that these methods arguably reflect semantically-informed decomposition and tap into different stages of processing.

On the whole, Orfanidou et al. (2011) reject the underspecification account of McCormick et al. (2008) as being unsuitable for cases of extensive and unpredictable changes. Instead they propose an account in line with Crepaldi et al. (2010) positing that in case of extensive stem alternations there are separate representations of the allomorphs which share some features in the semantic system. The authors note that this assumes two different stages of processing, that is morpho-orthographic and morpho-semantic stages. At the same time, Orfanidou et al. (2011) posit that *morphological/semantic* information is to some extent accessible in the masked priming as well. Similarly, our study may be also taken to indicate that even if the early stage of processing corresponds to the morpho-orthographic decomposition, semantic information is still not totally neglected as demonstrated by priming effects for verbs with stem changes.

Finally, the results of the present study of processing inflected forms with and without stem alternations could be compared to the study on French by Estivalet and Meunier (2016). In a

[13] Even more importantly stimuli in these studies are auditory, whereas the theory by Rastle and Davis (2008) was developed for visual processing.

nutshell the authors found a full priming effect for forms without stem alternations and only a partial effect for forms with stem alternations. Two possible explanations concerning the nature of the priming effects are provided. It is hypothesized that forms with stem allomorphy either have “linked stem representations activated in the prime and target or that they have abstract representations processed by morphological rules” (Estivalet & Meunier, 2016, p. 10). While the first explanation is essentially identical to the idea proposed by Crepaldi et al. (2010), the second one assumes allomorphic rules triggering changes at the stem boundary as a result of some morphophonological constraints. The authors indicate that both explanations cannot be excluded.

The possible rules and morphophonological constraints for Russian have been recently proposed by Magomedova and Slioussar (2015) who suggested a floating palatalization feature of -u inflectional ending for -i verbs. This, however, would not apply to groups of other verbs included in the study with much more idiosyncratic changes which are considered to be unpredictable based on morphophonological rules. The account which assumes existence of allomorphic rules would also predict stronger priming for verbs which are more supported by morphophonological rules or, in other words, number of words with similar types of allomorphic alternations (Fruchter et al., 2013).

The present experiment allows us to adjudicate between these two possible explanations suggested by Estivalet and Meunier (2016). There are indications against their second hypothesis, as there is no statistical difference between two groups of verbs with stem changes in Russian. It should be, however, repeated that the facilitation effect for verbs with stem changes as a whole is not distinguishable from the facilitation effect for words in the control sets which further complicates the discussion concerning any morphological sources of such an effect in the case of the verbs with stem changes.

Taken together, the results found in the present experiment concerning processing of inflected forms with and without stem allomorphy indicate a sharp dichotomy between them. This dichotomy may be restricted to access representations only as possibly indicated by studies tapping into a more central level of processing, for example, in Russian, Polish or Greek where large differences often completely disappear. The existence of such differences in our study as well as discussed studies in Greek and French may question the understanding of the processing at the level of access representations as being robust to orthographic changes. At least this seems to be the case in situations of extensive and often unpredictable changes in inflected forms compared to previously examined changes, such as, absent -e in English derived words as in *adorable – adore* (Orfanidou et al., 2011).

Considering the account by Crepaldi et al. (2010) and its application to Greek by Orfanidou et al. (2011) as well as French by Estivalet and Meunier (2016), it is possible that the reduced priming effect for stems with alternations arises through a different source than blind morpho-orthographic decomposition at least following initial stripping of the inflectional -u affix. The facilitation effect may be lexically-mediated and be due to the linked stem representations (*kos-* and *koš-*). The stronger facilitation effect for combinatorial forms of -aj verbs may indicate as discussed earlier full decomposition of such forms possibly down to the root (*igr-* in case of *igraj-u*). These possibilities are visualized in the following Figure 5:

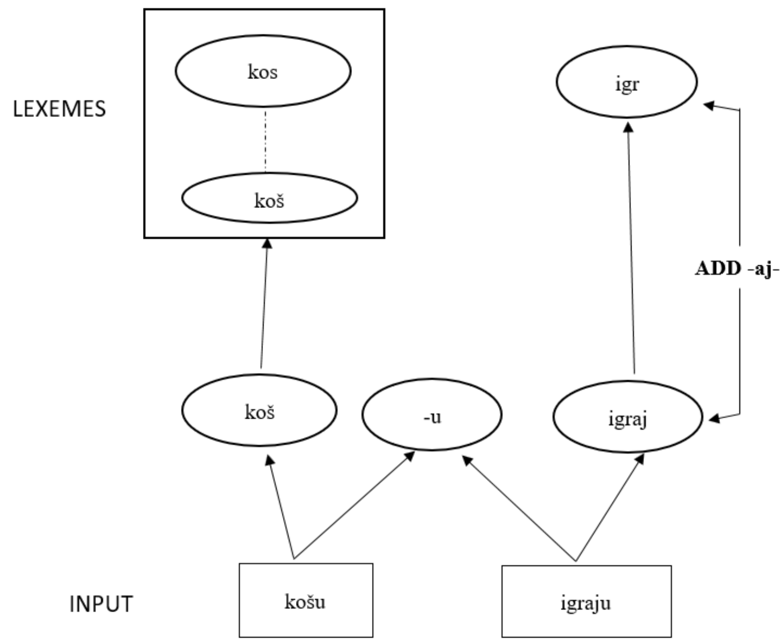

Figure 5. Word-form representations for inflected words with stem changes (e.g., -i verbs) and without stem changes (e.g., -aj verbs)

It should be stated, however, that interpretation of the facilitation effect as being lexically-mediated is somewhat questionable in the present study considering the statistically similar magnitude of facilitation for verbs with stem changes and the words in the control sets. On the other hand, it would appear to be not entirely obvious why morphological priming which is robust for words without stem changes would be fully reduced *only* to, for example, orthographic overlap for morphologically related words with stem alternations. Having observed similar patterns in Greek in the masked priming experiment, researchers have reported an increased facilitation effect for words with stem changes in the delayed priming experiment (Orfanidou et al., 2011) showing that presumably later stages of morphological processing are robust to orthographic opacity. This is an interesting prediction and although the present study has not tested it, there are indications that it may also hold for alternations observed in Polish and Russian based on the studies which explored processing at more central levels of representation (Gor & Jackson, 2013; Reid & Marslen-Wilson, 2002).

An interesting question is whether examined morphologically complex forms are decomposed pre- or post-lexically for lexical access. The differences could be summarized as follows: whereas morphological level of processing is postulated by both approaches, the location of morphemic units and their function are conceptualized differently. Whereas morphemic units act as access units in the sublexical approach and are positioned between the letter/syllable level and the word level, they are placed above the word-forms and before the semantic units and are considered to be intermediate units according to the supralexical or “whole word perspective” approach (Giraudo & Dal Maso, 2016). Therefore, according to the former view, access to word forms occurs via the pre-activation of the constituent morphemes. According to the latter, “recognition of any complex word initially triggers the activation of all word forms that can match with it, and a competition is then engaged between the pre-activated forms” (Giraudo & Dal Maso, 2016, p. 2). As a consequence, the supralexical approach places great value on paradigmatic relationships between words.

The present study does not allow us to adjudicate between two approaches since the theories which assume post-lexical processing of morphologically complex words usually experimentally manipulate the variables allowing to test whether morphological processing is influenced by factors beyond the surface structure of words, for example, morphological family size (Beyersmann & Grainger, 2017), base or surface frequency (Giraudo et al., 2016; Giraudo & Orihuela, 2015) and others.

Estivalet and Meunier (2016) who found a full priming for verbs without stem changes Estivalet and Meunier (2016) treat this effect as favoring pre-lexical processing claiming that such “verbs seem to undergo full decomposition that occurs pre-lexically and is used for lexical access and word recognition” (Estivalet & Meunier, 2016, p. 11). On the other hand, as discussed earlier, they also admit the possibility that priming effects in verbs with stem-allomorphy are essentially lexically-mediated. The lexically-mediated source of the priming effect for verbs with stem-changes in French is similar to the account by Crepaldi et al. (2010) for the priming in case of irregular verbs in English such as *fell – fall* which cannot be decomposed into any constituents. Beyersmann and Grainger (2017, p. 2) consider the account by Crepaldi et al. (2010) to be an instance of the supralexical account, however, not for all words but rather only “for inflected words, for which the lemma constitutes the supra-lexical representation of the family of inflected word forms”. Considering the possibility of the same account for the verbs with stem allomorphy in Russian the issue is far from being settled. In our experiment, we also observed a full-priming effect for derived words in the group of older speakers. This priming could be interpreted as being due to the nature of the derived words which are considered to preserve their morphological structure. Similar findings were reported numerous times in cross-modal as well as masked priming experiments discussed in the chapter 2.2 Previous Experimental Studies on Russian.

As masked priming experiments are usually interpreted as showing evidence of blind automatic affix-stripping parsing, priming effects observed in this experiment were expected especially considering absence of any stem changes which may have affected processing of the derived items even though such changes are apparently not always disruptive for the morphological decomposition as shown in the study by McCormick et al. (2008). Furthermore, the productivity of the affix and its frequency are also shown not to affect processing of derived words by native speakers (Dal Maso & Giraudo, 2014; Silva & Clahsen, 2008). Thus, even if unproductive or infrequent derivational affixes do not influence morphological decomposition in native speakers, robust priming effects for -ost’ nominalizations hardly come as a surprise.

It is also interesting that there are apparently no significant differences in the group of older adults for inflected -aj verbs with no stem changes and -ost’ derivation (also with no stem changes) both in terms of the amount of priming and its type (a full priming effect). This shows parallel mechanisms responsible for processing of derived and inflected forms which are often observed for native speakers and are in sharp contrast to findings for, for example, non-native speakers found in several studies (Jacob et al., 2017; Kırkıcı & Clahsen, 2013). The findings mentioned above indicate that under certain conditions (e.g., non-nativeness of speakers) linguistic differences between derivational and inflectional phenomena could be observed also in a masked priming study. Therefore, the direct comparison of priming effects for derived and inflected forms is of theoretic value in order to further specify the conditions under which the difference between processing of derived and inflected forms becomes salient. The experiments reported here on Russian indicate that the difference in processing of derived and inflected words may be restricted to L2 processing even though more studies are definitely required for a clearer picture.

A comparison of the derivation and inflection and the cross-linguistic validity of our findings would be also more directly addressed in the next chapter examining processing of complex words in German.

3 Part II. Experimental Study of Processing of Complex Words in German

3.1 Experiment I. Processing of derivation and inflection in German.

3.1.1 Processing of -ung derivation and -t participles in German. Introduction.

The present study uses the same design and materials as the experiment by Jacob, Heyer, and Veríssimo (2017) and focuses the on processing of derived -ung forms as well as inflected regular past -t participles in German. Similarly to the original study we also examine one of the less typical populations compared to healthy young participants but unlike Jacob et al. (2017) we chose to investigate processing mechanisms in older adults rather than language learners since it is one of the most understudied groups in psycholinguistics. However, the studies of more special populations clearly demonstrate that precisely in these groups one could observe contrasts which are relevant for the theories of language processing but are otherwise difficult to detect. For instance, the studies such as the one done by Jacob et al. (2017) and Kırkıcı and Clahsen (2013) found differences in processing derived and inflected words but only in the group of the language learners, that is a group which could be considered to be more "challenged" compared to the usually tested subjects. Since the design of the study allows the direct comparison between derived and inflected words we decided to test another group of such "challenged" subjects and namely older adults who might be affected by ongoing age-induced cognitive decline.

Additionally, the experiment reported below allows not only to compare morpho-syntactic processing of inflected words to morpho-lexical processing of derived words in German but also to compare our results cross-linguistically to the earlier reported findings on comparable phenomena in Russian. This comparison is also of great relevance considering the differences between languages, for example, in terms of the morphological richness or properties of the stems and the long-standing problem of cross-linguistic validity of numerous processing models which are usually based on English and may not be easily applicable to other languages. Furthermore, one could also investigate whether ageing similarly affects native speakers of Russian and German or whether observed patterns would be strikingly different. For instance, one has not observed any language-specific age-related effects for speakers of Hebrew and Spanish (Dunabeitia, Marin, Aviles, Perea, & Carreiras, 2009; Kavé & Levy, 2004) in contrast to German (Clahsen & Reifegerste, 2017). The experiment reported in the following chapters would make this cross-linguistic comparison possible.

Before we present the experiment itself and discuss its results, it is necessary to review the linguistic properties of the examined phenomena in German, that is of derivation by means of the -ung affix and inflected -t participles in German. This will be done in the following chapters.

3.1.1.1 A linguistic description of derivation by means of the -ung affix in German.

In the experimental literature examining properties of -ung derived forms statements as following are rather usual: "Deverbal −ung forms are fully productive and semantically transparent, that is, when a verb denotes an action, the corresponding deverbal noun in −ung describes the consequence or result of the action" (Clahsen, 2003, p. 17). While it is true that one can derive a noun from the verbal stem as in the case of *Gründ-ung* 'founding' from *gründen* 'to found', it is also not possible for a large number of verbs such as *wischen* 'wipe' and *arbeiten* 'work'. Thus, the representation of the derivational rule by Clahsen et al. (2003) as <[V, LEX], X> → <[N, LEX+UNG], X+UNG> does not apply to a large number of verbs. In what follows, I will examine some of the constraints on the formation of the -ung nouns.

One of the approaches examining properties of -ung derivation considers diachronic changes. Based on the analysis of the existing corpora one could notice the reduction in productivity of -ung derivation and emergence of semantic constraints (Demske, 2000; Hartmann, 2013, 2014) as -ung affix cannot be applied anymore to state verbs, durative verbs or inchoative verbs.

The main claim is that -ung nominals evolve into more prototypical nouns due to the process of lexicalization. This change can also be considered as a shift from more "verby" nouns describing for example processes and events (e.g., *bei Lesung* 'while reading') towards more "nouny" nouns (e.g., *Heizung* 'heating device' or *Begleitung* 'company') on the scale introduced by Hartmann (2014a).

There were several attempts at determining constraints affecting formation as well as meaning variability of the -ung nouns. Shin (2001) noticed that verbs derived from adjective stems allow -ung nominals, whereas prefix verbs with a verb stem do not (e.g., compare *vereinsamen* 'to become isolated' vs. *verlaufen* 'getting lost' respectively). To account for this difference Shin (2001) hypothesized that the event structure in verbs allowing -ung derivation has interval properties. Consider the example *der Mann erblindet* 'the man becomes blind': "a source state (SS), at which the man is not blind; a target state (TS), at which he is blind; and a change between these" (Shin, 2001, p. 305).

In contrast, even though *erblühen* may also include the steps described earlier, the target state lacks a clear-cut point in time within the "change interval" when the flower is not blooming.

The same difference would also apply to the transitive verbs. The account by Shin (2001) also allows to partially explain ambiguities in meaning as nominalization may focus more on the transition interval or on the result state which leads to either durative or resultative meanings.

Scheffler (2005) criticized the account by Shin (2001) as it is not general enough and cannot account for the nouns such as *Vermeidung* ‘avoidance’ with no clear target state. Moreover, it is not clear why the difference in semantics between *erblühen* ‘to start blossoming’ and *erblinden* ‘to become blind’ should matter with regard to building -ung nouns. Scheffler (2005) summarizes the factors which affect the ability of a verb to derive -ung nominals as follows: telicity, prefixation and the nature of the verb stem (noun/adjective vs. verbal stems).

Finally, the most exhaustive account of the -ung derivation has been developed by Roßdeutscher (2010) and Roßdeutscher and Kamp (2010). Instead of the distinction between verbs with denominal or deadjectival bases from deverbal ones, which could be also seen as a contrast between sortal and property-denoting verbs versus manner verbs, Roßdeutscher and Kamp (2010) distinguish between mono-eventive and bi-eventive verbs claiming that -ung nominalizations could be derived only from the latter. This difference corresponds to core transitive and non-core transitive verbs in terms of Levin (1999) who suggested the following structures:

(i) [[x ACT<manner>][CAUSE [BECOME [y <STATE>]]]]

(ii) [[x ACT<manner>, y]]

To illustrate the difference Roßdeutscher and Kamp (2010) examine two verbs with similar meanings such as *säubern* ‘to clean’ and *wischen* ‘to wipe’ which both can take direct objects. Only *säubern* ‘to clean’, however, is considered to be core transitive and bi-eventive whereas *wischen* ‘to wipe’ is actually non-core transitive and mono-eventive. The difference is the nature of the relationship between the direct object and the event denoted by the verbal structure. Whereas in case of *säubern* this relationship is considered to be causal, in case of *wischen* it is not. The root √wisch is assumed to be a “manner” root which acts simply as predicate of the event without any causality implied. Thus, this account makes it possible to explain a puzzling problem of why only some transitive verbs allow -ung nouns.

However, this explanation may have an apparent problem as in some cases prefixed verbs allow -ung nouns even though the base word did not (e.g., *arbeiten* ‘to work’ – *bearbeiten* ‘to work at’ – *Bearbeitung* ‘editing, processing’) even though the majority of such prefixed verbs do not have corresponding -ung nominals. Roßdeutscher (2014) claims that what happens in this case is a *coercion* of manner roots to result state denoting roots (the same applies to other prefixes such as ver-, zer- and particles ein, ab) triggered by properties of be- prefix which produces bi-eventively constructed verbs. However, even the account by Roßdeutscher and Kamp (2010) is not able to account for numerous -ung nouns as they either have no systematic semantic relationship to the base verb (e.g., *Währung* 'currency', *Spannung* 'tension') or problematic for the syntactic analysis (e.g., *Zeitung* 'newspaper', *Gattung* 'species').

In sum, derivation of nouns by means of the -ung affix is highly productive in German, though there are certain constraints regarding its productivity. The derived -ung nouns may also exhibit some variability with regard to semantics which is not always predictable from the semantics of the corresponding verbs. Thus, the formula proposed by Clahsen et al. (2003) as <[V, LEX], X> → <[N, LEX+UNG], X+UNG> appears to be applicable only to some verbs. Though properties of verbs allowing -ung derivations are not completely understood yet, there are indications that they are related to the event/phase structure of the verbs as proposed by Shin (2001) and Roßdeutscher and Kamp (2010). If future studies lend support to these claims, the schematic representation of the -ung derivation should integrate the constraints by specifying the nature of the verb.

In any case, these constraints are often semantic and are not critical for the present study since we focus on the processing on the derived -ung nouns and their decomposability rather than semantic properties of the verb roots as such. The derived nouns included in the present study were semantically transparent and clear instances of productive derivation (such as *Änderung* 'a change' – *ändern* 'to change'). No idiosyncratic cases (such as *Währung* 'currency', *Böschung* 'embankment' or even *Heizung* 'heating device' etc.) were included.

3.1.1.2 A linguistic description of past participles in German.

The present chapter will focus on past participles, their formation and some related controversies. Traditionally German has been described as having three types of verbs: weak, strong and mixed. This classification is based on the following properties: whereas participles from the weak verbs are formed by means of the -t affix and involve no stem or root changes, it is not true for two other classes of verbs. Thus, the main difference of the verbs attributed to the mixed classes is that even though the participles are also built using the -t affix, these verbs show stem changes. There are only 13 verbs of the mixed type in German (e.g., *bringen* 'to bring' and *rennen* 'to run').

Strong verbs differ from both weak and mixed verbs as they take -n affix to form past participles and in addition to it may also exhibit stem changes in various forms. Some of these properties could be listed as follows: "(i) The preterite vowel always differs from that of the base. (ii) The participle is always formed with the suffix /n/ (iii)… (iv) 2nd and 3rd singular present indicative are mostly formed with a front vowel" (Wunderlich & Fabri, 1995, p. 255). There are around 180 verbs of this type which could be further subdivided into subclasses based on the subregularities among these verbs.

Wunderlich and Fabri (1995) assumed that the lexical entries of strong verbs in German include not only a base but also subnodes adding phonological information in contrast to weak verbs investigated in the present study which only have the base node. Bittner (1996) criticizes the sharp distinction between weak and strong verbs in German and claims that the differences represent a continuum with some verbs being typical examples of strong words, for example, *lesen* 'to read' and others such as *mahlen* 'to grind'. The only feature of the *mahlen* 'to grind' which allows to treat it as a strong verb is the past participle form *gemahlen* built by means of -n affix. This approach does not run against the claims made by Wunderlich and Fabri (1995) as they also admit the possibility that some subnodes of strong verbs could get lost (e.g., *stecken* {stek, stark+pret} 'stick' with regularly built *gesteckt*).

Note that the approach by Wunderlich and Fabri (1995) apparently contradicts the account by Wunderlich (1992) who assumed a disjunctive rule to explain the formation of participles:

a. Insert /n/ in $[[+\text{PART}]_{[+V]} \_\_\_]_{[+V,+PART]}$

b. Insert /t/ in $[[\quad]_{[+V]} \_\_\_]_{[+V,+PART]}$

Wunderlich (1992) essentially suggests that verbs having a participle stem take -n affix, whereas all other take -t. From the theoretical point of view, this assumption according to Wunderlich and Fabri (1995) runs against the redundancy constraint which stipulates that output information should not be included in the input. The main difference is that Wunderlich (1992) assumes rule-based affixation for both -t and -n affixes, whereas Wunderlich and Fabri (1995) assume separate lexical entries for -n participles.

In sum, the approach by Wunderlich and Fabri (1995) views -n forms as having internally structured lexical entries with -n being not a regular affix but a part of the lexical entry. In contrast to this, all the forms which are not listed in the lexical entry of a verb are generated by means of regular affixation. Thus, this approach treats -t participles as being affix-based and -n participles as representing lexical entries. This distinction could be used to account for the differences in productivity of -t and -n. Application of -t is rule-based, therefore, could extend to any novel item. In contrast to this, -n is unproductive with exception of some rare cases of analogy-based productivity (Wunderlich & Fabri, 1995). This contrast between participles would predict differences in mechanisms responsible for processing -t and -n forms.

A different explanation for the productivity differences of the patterns is defended by Bybee (1995) who considers it to be a natural consequence of the differences in type and token frequency. According to the analysis by Bybee (1995) in the list of 1258 base verbs, only 12% are strong (irregular) verbs which is similar to the type frequency pattern observed in English. Therefore Bybee (1995) claims that the proposed default status of -t in German is similarly to the English -ed also confounded with its type frequency and the productivity simply reflects it.This runs against the data provided by Clahsen and Rothweiler (1993) who consider the distribution of strong and weak words as being fairly comparable having, however, calculated prefixed words as separate entries.

Marcus et al. (1995) show that the approach by Bybee (1995) is highly questionable as she is against treating separable-prefix verbs in German such as *aufhören* 'to stop' as distinct verbs and suggests calculating only root verbs such as *hören* 'to hear'. Traditionally, though, separable-prefix verbs were always considered to be distinct verbs similarly to *overcome* and *become* in English. Moreover, they act orthographically and phonologically as single units, and the meaning is often not compositional as German examples above illustrate. In addition Marcus et al. (1995) note that German children appear to treat these verbs as unanalyzable. Thus, Marcus et al. (1995) reject the key argument by Bybee (1995) who views the constrast in productivity between weak -t and strong -n participles as being due the differences in type and token frequency rather than due the opposition between rule-based affixation of -t participles and lexical storage of -n participels.

Another phenomenon which should be discussed with regard to past participles in German is the status of the ge- element. The ge- prefix is assumed to have no semantic or morphological consequences and its the distribution is determined prosodically by the following constraint as stated (Wunderlich & Fabri, 1995, p. 265): "ge- is prefixed to a participle if the initial syllable bears primary stress". One could illustrate it by following examples: *káufen* 'to buy' – *gekauft* vs. *spazieren* 'to go for a walk' – *spaziert*.

The similar argument is also made by Wiese (2000). The ge- prefixation follows the assignment of the prosodic structure so that the whole procedure of past participle formation in German is represented by Wiese (2000, p. 93) as follows:

a. /pʀe:dig/	lexical entry
b. $_{\omega}$[$_{F}$ [pʀe:dig]]	prosodic structure assignment
c. [[pʀe:dig]$_{V}$ t]$_{[+part, +past]}$	formation of participle
d. $_{\omega}$[gX $_{F}$ [pʀe:dig] t]	*ge*-Prefixation (11)

Note, though, that Wiese (2000) identifies another difference between words which receive ge- prefix and those that do not. Only the words having one foot obtain ge- prefix (e.g., *ge-lernt*, *ge-*

predigt) whereas those with two feet do not (e.g., *schmarotzt*, *diskutiert*). Hence, it is assumed that not the stress but rather the prosodic structure of the verb plays the crucial role, so ge-is applied if the phonological word consists of only one foot. This constraint applies not only to participles but to nouns as well (e.g., *Geschrei* vs. ~~*Ge*~~*-spektakel*). The analysis by Wiese (2000) positing the ge-prefixation as the last step after the assignment of the prosodic structure and formation of the participles to ensure the correct phonological structure convincingly argues against treatment of ge--t as a circumfix (Lieber, 1992; Meibauer et al., 2007).

Wiese (2000) also briefly addresses the distribution of the schwa in -(e)t affix (cf. *spielen* 'to play' – *gespielt* vs. *arbeiten* 'to work' - *gearbeitet*). The presence or absence of the schwa is determined by the nature of the stem-final consonant. If it is either -d or -t as in *arbeiten*, then schwa in inserted, otherwise as in *spielen* it is not.

Another question which should be addressed is whether past participles are inflected or derived forms. Usually past participles are considered to be inflected forms, as analyzed by Wunderlich and Fabri (1995) who distinguish between finite forms and non-finite forms, such as infinitives and participles. The participle and infinitive forms are distinguished by means of the feature [part], with participles being classified as [+ part] in contrast to the maximally unmarked verb form such as infinitive [- part]. Thus, even though participles are indeed not inflected for person or number they must be dissociated from infinitive forms and thus could not be claimed to be fully uninflected. We therefore treat participles as inflected forms in line with the more common approach following Clahsen (1999a), Clahsen and Fleischhauer (2014) and Jacob et al. (2013).

However, there are also alternative views. For instance, Blevins (2001) notes that participles could be used in an attributive function in which case participial exponents -t or -en are followed by adjectival endings. Thus, if participles are considered to be inflectional, then a single form should be allowed to bear simultaneously two inflectional endings: -t/-en and adjectival agreement endings. Apparently, two inflectional endings are considered to be highly unusual. Therefore, treating -t/en affixes as derivational should be preferred according to Blevins (2001). Later Blevins (2014) suggested a different solution claiming that if these forms are treated as "neutralizing the categorical distinction between verbs and adjectives, they can be included in the lexeme of a verb provided that the lexeme is defined as a set of grammatical words with non-contrastive … values for word class" (Blevins, 2014, p. 8). Thus, apparently participles could be still viewed as inflected forms.

The central idea of the account by Blevins (2001) is based on the strict dichotomy between inflection and derivation on the one hand and paradigmatic and lexeme-creating mechanisms on the other hand. While inflection is indeed paradigmatic, Blevins (2001) denies that all paradigmatic processes are in their turn also inflectional. In essence, participles should be viewed as instances of paradigmatic derivation and -t forms in German should be considered as second stems of the verbs (Blevins, 2003). This approach was rejected by Clahsen et al. (2003) who rely on the opposition between derivational or lexeme formation processes on the one hand and inflectional or paradigmatic processes on the other hand and accordingly classify participles as inflectional forms. In line with this view and the approach suggested by Blevins (2014) we treat past participles in German as inflected forms.

Finally, -t affixation in German is not only productive as productivity could be also analogy driven, it is considered to be the default pattern in German (Marcus et al., 1995). One could test these claims by applying the criteria proposed by Marcus et al. (1995) and adopt them in the present study. The default status essentially implies unrestricted ability to apply to any item provided there is no already precomputed output (e.g., existing -en participles). This could be demonstrated by several criteria such as the application to novel words (e.g., *simsen* 'to send sms') regardless of their phonological similarity to already existing German verbs, to low-frequency words, to onomatopoeic words, to verbs derived from other categories (e.g., denominal verbs), to verbs homophonous with strong verbs etc. All these requirements are apparently fulfilled by -t affix in German.

To sum up, -t affixation in German is considered to be rule-based so that -t participles are in contrast to -n participles not stored as internally structured lexical entries in the mental lexicon (Wunderlich & Fabri, 1995). Application of -t affix is highly productive in modern German and in contrast to -ung nominalization described earlier is virtually unconstrained (except for a limited set of strong -n verbs). Furthermore, application of -t affix is traditionally treated as an inflectional process which spells out a morphosyntactic feature [+ part] as suggested by Wunderlich and Fabri (1995). These properties of -t participles described above would serve as a basis for comparison to -ung nominalizations in the present study.

3.1.2 Previous experimental studies on German derivation and verbal inflection.

In this chapter we will review findings from studies on processing of derived and regular inflected forms in German and will focus mostly on studies employing a priming technique as it was also used in the present study and would thus facilitate the comparison of the obtained results. We will begin by examining studies which focus on processing mechanisms of derived words.

One of the first studies which examined among others the processing of such words in German was conducted by Sonnenstuhl, Eisenbeiss, and Clahsen (1999). They conducted a cross-modal priming experiment which included derived diminutive nouns with and without vowel change (e.g., *Dach* ‘roof’ – *Dächlein* and *Licht* ‘light’ – *Lichtchen*, respectively). Importantly, vowel changes in the diminutives are completely predictable and rule-based due to a phonological rule of fronting. The authors found that a completely predictable vowel change does not affect the magnitude of priming as both groups of nouns yielded full priming effects. These findings were interpreted as showing decomposition of derived forms into stems and affixes and also allowed to show independence of priming effects from surface-level similarity between words.

Later, Clahsen et al. (2003) examined processing of derived nouns with nominalization and diminutive affixes (*-ung* and *–chen* accordingly) by means of a lexical decision task and a cross-modal priming experiment. In the unprimed lexical decision experiment they manipulated word-form frequency of the nouns by including nouns with high and low surface frequency. As it was established that high-frequency nouns were recognized faster than nouns of lower frequency, Clahsen et al., (2003) took this as evidence for availability of full-form representations for the derived nouns.

In the same paper, Clahsen et al. (2003) reported a cross-modal priming experiment which included identity, related and unrelated conditions. Crucially, the primes in the unrelated conditions were nouns derived by means of the *-ung* suffix with the corresponding infinitive forms as targets. The statistical analysis revealed a full priming effect as response latencies in the related condition after presentation of derived *-ung* nouns as primes were similar to those as in the identity condition with base verbs as primes while at the same time being significantly faster than any following unrelated primes.

These findings were interpreted as allowing one to specify the nature of the representations of the derived words in the mental lexicon. Thus, derived words are seen as combinatorial entries being stored in the mental lexicon while still preserving their morphological structure as shown by the results from the lexical decision task which revealed surface frequency effects usual for lexical entries. A full priming effect in the cross-modal priming experiment was taken to indicate decomposition which activates a shared stem in both prime and target words (Clahsen et al., 2003).

Importantly, a full priming effect is not limited to the lemma level processing. In the masked priming study which examined processing of *-ung* derived nouns in German conducted by Clahsen and Neubauer (2010) a full priming effect elicited by native speakers was also found. The results of this experiment were also interpreted as indicating decomposition of such complex derived forms into their corresponding constituents.

Processing of participles in German was investigated in several studies which mostly focused on differences between regular and irregular participles. For instance, Sonnenstuhl et al. (1999) conducted a cross-modal priming experiment including two groups of verbs including regular participles (e.g., *geöffnet* 'opened') and irregular participles with no vowel change (e.g., *geschlafen* 'slept'). The 1st person singular present tense form was used as a target. They found differences in processing, namely a full priming effect for regular verbs and a partial priming effect for irregular verbs. These findings were interpreted in favor of decomposition of regular verbs and involvement of lexical look-up during processing of irregular verbs.

A similar claim regarding the processing of regular inflected verbs by native speakers in German was put forward in a study by Neubauer and Clahsen (2009). They conducted a masked priming study with a design similar to the study by Sonnenstuhl et al. (1999) which produced parallel results with a partial priming found for irregular verbs and a full priming for regular *-t* participles.

On the other hand, Smolka, Zwitserlood, and Rösler (2007) came to different conclusions than Sonnenstuhl et al. (1999) as they failed to observe any difference in priming effects between regular and irregular participles. However, as Fleischhauer (2013) notes, the study could be criticized for not having included an identity condition which thus did not allow to differentiate between full and partial priming effects. Furthermore, the primes and targets were visually presented while primes were not masked which in absence of semantic and orthographic control sets complicates interpretation of the observed priming effect as being truly morphological in nature because the obtained priming effects could be also interpreted as being due to the form/meaning relatedness between primes and targets.

In a recent ERP priming study Smolka, Khader, Wiese, Zwitserlood, and Rösler (2013) argued against a dichotomy in processing of regular and irregular verbs. They have conducted an EEG and behavioral experiments using the same materials which included not only regular verbs (infinitive stems/ -t affix) but also semi-regular (infinitive stem/ -en affix) and truly irregular verbs (vowel change/ -en affix). Contrary to the previous studies, which found what was considered to be "categorical" or binary differences between processing of regular and irregular forms such as N400 reduction or absence of it, they found more gradual differences in processing regular, semi-regular and irregular verbs.

The analysis of the electrophysiological data revealed graded priming effects with stronger and more broadly distributed effects for regular participles, less so for semi-regular verbs and only minimal for irregular verbs. These findings were interpreted against the assumptions of the dual-route model which would predict a "dichotomous differentiation between a regular system and an irregular system—independent of the "amount of irregularity"—and thus predict parsing effects for "regular" participles in contrast to similar retrieval effects for "irregular 1" and "irregular 2" subgroups"[14] (Smolka et al., 2013, p. 1290).

The authors hypothesized that the observed N400 modulations for all verbs contradict the dichotomy between grammatical processing for regular verbs (LAN, P600) and more semantic processing for irregular verbs (N400) which would be in line with the dual-route approach. Instead, the provided explanation ascribed graded differences to a variation in type and token frequency between various types of stems which is in line with a model which would assume that *all* complex verbs are parsed into stem and affixes and are lexically represented via their constituents (Smolka et al., 2013). Regular stems occur in various other inflected forms in addition to participles, whereas stems of semi-regular and irregular participles occur in a fewer number of inflected forms which would account for stronger activation of regular participles.

In the response latency data, they found partial priming effects for all groups of verbs and contrary to earlier reported studies no full-priming effect for regular verbs was found. Crucially, however, even though Smolka et al. (2013) disagree with conclusions from the previous studies regarding differences in processing regular and irregular participles in German, they criticize only the view that irregular participles are retrieved unanalyzed as whole-word units. According to the obtained results all verbs are supposedly decomposed during processing and mechanisms responsible for processing of all types of verbs in German are essentially the same. The mechanism of decomposition-based processing of regular *-t* participles is not called into question.

In sum, the studies which examined the processing of regular -t participles in German produced results which indicate the decomposition of such forms into constituent morphemes during recognition of such forms. This claim resembles hypotheses regarding processing of derived words

[14] "Irregular 1" and "irregular 2" subgroups refer according to Smolka et al. (2013) to semi-irregular participles comprising the (unchanged) stem and the -en suffix, and completely irregular participles which have a stem with vowel change and the -en suffix respectively.

in German since the majority of studies cited in this chapter supports a decomposition-based account of processing of such forms backed up by priming experiments. It is also true that there is some conflicting evidence which appears, at least *prima facie*, to be not compatible with the decomposition-based account of processing posited for derived words. For instance, Clahsen et al. (2003) reported a full-form frequency effect for derived words in an unprimed lexical decision experiment, that is that high-frequency nouns were recognized faster than nouns of lower frequency. It was argued that these results show the availability of full-form representations for the derived nouns. However, this should not necessarily be a challenge for the priming experiments showing decomposition-based processing of such forms. Instead these results may actually highlight the nature of the derivation which represents the result of combinatorial operations but is associated with stored entries.

The differences could be considered to be task specific as unprimed lexical decision experiments encourage the search for traces of a word in the memory and thus tap into stored full-form representations (Clahsen et al., 2003) whereas the priming experiment is assessing the "ability to use morphological mappings in order to take advantage of the prime in processing the target word, and does not favour access of whole-word representations or is not a sensitive measure for it" (Gor & Jackson, 2013, p. 23). Similarly, the task differences could also be thought of as showing the differences between the mechanisms of the lexical access and organization of the mental lexicon itself as "the factors driving the early stages of processing are likely to be different from those coded in long-term memory" (Giraudo & Dal Maso, 2016, p. 2). Thus, the results of the masked priming studies indicating decomposition of the derived words on the one hand and from unprimed lexical decision experiments showing surface frequency effects on the other hand do not contradict but complement each other.

Note also a different understanding of the surface frequency proposed by Baayen, Wurm, and Aycock (2007) who criticize the surface form frequency as a reliable measure of the whole-word access. They suggest that it reflects "the syntagmatic combinatorial properties of morphological formatives" (Baayen et al., 2007, p. 425). The phrase "combinatorial properties" in this case does not refer to the summed frequency of the constituent morphemes. Instead, the following explanation is provided. In case of the word *hatless* the surface frequency of the word is "an estimate of the joint probability of *hat* and *-less*, i.e., as a contextually conditioned, syntagmatic probability that supports *hat* as a real meaningful constituent" (Baayen et al., 2007, pp. 424–425) and allows to discard *hat* as as a constituent in the word *chat*. Surface frequency is interpreted as a co-occurrence probability of morphemes. In other words, surface frequency in the complex words reflects the joint probability of the constituents based on previous experience in integrating them and reflects decompositional properties of the complex words. This account would be reconcilable with the assumptions made by Clahsen et al. (2003) and in other studies concerning decomposition-based processing of derived -ung nominalizations in priming experiments.

However, priming effects of derived and inflected words were until recently never assessed on the same target in German. The only notable exception is the study by Jacob et al. (2017). Since its design and its materials were used for the present study, see the Chapter 3.1.5 for more details. The study used infinitives as targets (e.g., *ändern* 'to change') and derived (e.g., *Änderung* 'a change') as well as inflected forms (e.g., *geändert* 'changed') as primes.

The main focus of this study was to compare processing of inflected and derived words by native and non-native speakers. Jacob et al. (2017) found that whereas native speakers showed priming effects (partial priming) for both derived and inflected words in line with the findings from studies mentioned above, non-native speakers showed no facilitation after inflected primes compared to unrelated primes. This contrast in priming effects found for a specific population is of great interest, as it stresses linguistic differences between inflection and derivation. This study also underscores the importance of comparing various groups of speakers in order to refine existing theories of morphological processing which often rely on data from the group of participants in mid-twenties who are college students and may not necessarily be applicable to other groups.

The observed contrast in processing derived and inflected forms by language learners may be due to the different properties of derivational or inflectional affixes or due to the differences in the nature of the derived and inflected words. For instance, whereas the application of *-t* affix is essentially the spell-out of the morphosyntactic feature, *-ung* affix creates a new lexeme. Alternatively, the derivational affix carries a semantic meaning which makes it more salient for L2 speakers compared to inflectional affixes which lack that meaning (Jacob et al., 2017).

Even though the studies reviewed here found similar decomposition-based processing of both derived and inflected words, it is worth keeping in mind, that as mentioned earlier they usually focused on typical young native speakers of German. It is possible that differences in processing mechanisms of derived and inflected words would be found for other special populations rather than only for language learners considering our lack of knowledge with regard to any other group other than "predominantly highly-educated students of which a large majority is female" (Baayen, 2014, p. 101). As studies including language learners have already demonstrated, testing special populations could provide useful insights with regard to competing accounts of morphological processing and reveal the linguistic differences, for instance, between derivation and inflection which may otherwise be hard to observe.

In the following paragraphs we will consider several possibilities with regard to processing of derived and inflected words in older adults. It should be acknowledged that we might expect age-related changes mostly in processing of derived words since processing of inflected words is considered to rely on the highly automatized decomposition-based mechanism and procedural memory which is assumed to remain stable with advancing age. On the other hand, if the assumption that processing of derived words is lexically-mediated (i.e., involves more reliance on memory) is true not only for L2 speakers, one may assume reduced facilitation in older adults compared to a facilitation effect for regularly inflected verbs. This assumption is based on existing indications in the literature on ageing that, for example, declarative memory in older adults may be negatively affected by ageing (Harada et al., 2013; Rönnlund et al., 2005)

Alternatively, it has also been recently claimed that "greater age and, thus, greater experience with complex forms facilitates storage-based access" (Reifegerste et al., 2017, p. 485). In this case stronger priming for derived words in older adults could also be expected. In other words, if the mechanisms employed by, for example, older adults, are found to be different from the what is usually found for younger people due to age-related differences, it may provide valuable insight into theoretical questions with regard to linguistic differences between derivation and inflection.

The experiments reported below will focus on processing of derived and inflected words and possibly aid us to specify the conditions under which these differences become detectable as well as establish whether the linguistic differences are restricted only to non-native speakers. The main focus of the experiment on German is examining effects of ageing on processing of derived and regularly inflected forms and establishing whether such effects are language specific and limited to particular linguistic phenomena (e.g., processing of complex forms which may rely on storage-based mechanisms of recognition). Alternatively, these effects may be global and consist in slower response latencies and/or higher accuracy rates with advancing age. Crucially, we are not aware of a single study on German which would address these questions by examining the processing of derived and inflected words in older adults and comparing to the control group of younger speakers.

The present experiment seeks to provide answers to the questions left open in earlier studies and to constrain theories on morphological processing and examine the effects of ageing on processing of derived and regularly inflected words in German.

3.1.3 Participants.

32 older native speakers of German and 40 younger native speakers of German participated in the experiment. All participants were living in Germany at the time of testing, had normal or corrected-to-normal vision and hearing, gave their informed consent, and were paid for their participation in the study.

All older participants included took part in the neuropsychological test battery of the Consortium to Establish a Registry for Alzheimer's Disease (CERAD-Plus; www.memoryclinic.ch). The CERAD composite score (Chandler et al., 2005) is the sum of several subtests including Verbal Fluency (Animal Naming), the modified Boston Naming Test, Constructional Praxis as well as Word List Learning, Recall, and Recognition Discriminability. The possible maximum cannot be more than 100.

Five of the mentioned subtests (Verbal Fluency, Boston Naming Test, Word List Learning, Word List Recall, Word List Recognition) assess verbal memory performance. Therefore, the CERAD score could be seen as a proxy of verbal memory. The ratings of cognitive performance we obtained from older German adults are typical in healthy cognitive ageing.

See Table 14 for demographic details on all participants. Data for the younger speakers were taken from Jacob et al. (2017).

Table 14

Demographic Information on Participants in the Study on -ung Nouns and -t Participles in German

	Older group			Younger group[15]		
Number	32			40		
Sex	7 males, 25 females			12 males, 28 females		
	mean	SD	range	mean	SD	range
Age	64.6	9.3	51-83	23.9	4.5	18-40
CERAD	89.4	5.4	79-98	-	-	-
MMSE	29.2	0.83	27-30	-	-	-

[15] The biographical information regarding younger speakers is taken completely from the study by Jacob et al. (2017)

3.1.4 Procedure.

The procedure of the present experiment testing older speakers of German was developed by Jacob et al. (2017) for younger native speakers of German. In what follows it will be described in greater detail.

Participants were tested individually in a quiet environment using the DMDX testing software (Forster & Forster, 2003) for stimulus presentation and data collection. Each participant was randomly assigned to one of the presentation lists.

Each experimental trial started with a 500ms blank screen followed by a forward mask consisting of hash marks (of the same length as the prime word) for 500ms. The forward mask was followed by a prime word which was shown for 50ms. The target word appeared immediately after the presentation of the prime and remained visible until the participant had made his decision, but not longer than for 500ms.

Participants were instructed that they would see letter strings on the computer screen and were asked to decide as quickly as possible whether these strings were existing German words or not by pressing either the ‘YES’ or the ‘NO’ button on the gamepad, with the dominant hand controlling the ‘YES’ button. RT measurements started with the presentation of the target word. If the participant did not produce a response within 5000ms, a new trial started. There was no feedback on accuracy. Before the experimental session, each participant underwent a practice section consisting of 10 prime-target pairs.

At the end of the experimental session, all participants were asked to describe what they saw on the screen during the session to ensure that they were unaware of the primes. No participant reported noticing any of the prime words either after the practice session or at the end of the experiment.

The experiment lasted approximately 15-20 minutes.

3.1.5 Design and predictions.

The design and experimental materials of our study were taken from Jacob et al. (2017). The information on matching reported below is taken from that study.

The study included a morphological test set as well as a semantic and an orthographic control set. The morphological set included 28 prime-target pairs. All target words were infinitive forms (e.g., *ändern* ‘(to) change’) and were preceded by either (i) an identity prime, (ii) the past participle form of the same verb (e.g., *geändert* ‘changed’), (iii) the derived nominalization (e.g., *Änderung* ‘the change’), or (iv) an unrelated prime (e.g., *klein* ‘small’).

Both the inflectional and the derivational affix consist of three letters attached to the stem of the verb (ge-t, -ung), allowing the inflected and derived prime words to be matched for length. Half of the unrelated primes were nouns, the other half were adjectives, semantically and orthographically unrelated to the target word. Across all prime-type conditions, prime words were matched for word form frequency based on the values provided in the webCELEX database (all ps > 0.258); primes in identity and control conditions were further matched for the length in letter ($t(27) = -1.41$, $p = 0.170$).

Due to the fact that primes and targets in the morphological set are not only morphologically but also semantically and orthographically related, an orthographic control set and a semantic control set were included in the study to assess the amount of orthographic and semantic priming.

Each of the two control conditions (semantic and orthographic) contained 24 experimental targets, preceded by three types of primes: identity, related, and unrelated. Targets in the semantic and orthographic sets were matched for word-form and lemma frequency to the morphological targets. The degree of overlap between orthographically related and morphologically related primes and targets was also matched. The unrelated primes in semantic and orthographic sets were of similar length as well as word-form and lemma frequency (all *t*s < 1).

The information regarding word form frequency, lemma frequency and the length of the experimental items is provided in the Table 15 taken from Jacob et al. (2017). For the matching details and further information, refer to Jacob et al. (2017).

Table 15

Length and Frequency Information (WFF Stands for Word Form Frequency, LF for Lemma Frequency, Length for Word Length in Letters) for Three Item Sets

	Morphological set					
	Primes			Targets		
	WFF	LF	Length	WFF	LF	Length
Derived	27.6	37.2	7.8			
Inflected	22.1	82.6	7.9	23.8	82.6	6.4
Unrelated	23.1	62.8	6.3			
	Orthographic set					
	WFF	LF	Length	WFF	LF	Length
Related	31.6	83.0	6.8	36.3	71.5	5.5
Unrelated	32.0	91.2	6.5			
	Semantic set					
	WFF	LF	Length	WFF	LF	Length
Related	107.6	142.8	5.1	86.3	120.1	4.8
Unrelated	83.0	150.0	5.1			

Note. Adapted from “Aiming at the same target: a masked priming study directly comparing derivation and inflection in the second language” by J. Gunnar, V. Heyer, and J. Veríssimo, 2017, *International Journal of Bilingualism, 1*(19), p. 7. Copyright 2017 by SAGE Publications.

324 fillers were added to the 76 experimental items (28 morphological pairs, 24 orthographic pairs, 24 semantic pairs), with half of the targets being existing words in German and half being nonwords created by changing one to three letters in existing words. Primes and targets were nouns, verbs, and adjectives in equal proportions. The number of related items was less than 19%. Four experimental lists were composed based on a Latin square design so that each target word was presented only once to a participant. The lists were presented in reversed order to half of the participants (see Appendix C for the list of all critical items).

Based on previous research on morphological processing and ageing several possible outcomes could be predicted:

1) Similar priming effects for both derived and inflected words (Jacob et al., 2017) in older adults and no difference relative to younger adults indicating preserved decomposition-based processing (Duñabeitia et al., 2009; Kavé & Levy, 2004)

2) Less facilitation for derived words than for inflected words in adults which could mean a decline of the declarative memory with ageing (Clahsen & Reifegerste, 2017)

3) Alternatively, more facilitation for derived words than for inflected words indicating greater experience of older adults which boosts storage-based access (Reifegerste et al., 2017)

4) Higher accuracy and slower response latencies in older adults indicating speed-accuracy trade-off as predicted by Ramscar et al. (2014)

3.1.6 Data analysis.

The original raw data from Jacob et al. (2017) were used for comparison purposes only and were analyzed using the same procedures as for all other experiments reported in the present study. There are two main differences from the analysis by Jacob et al. (2017). Firstly, in order to normalize RT distributions and to reduce the influence of outliers Jacob et al. (2017) applied fixed cutoff points and removed all RTs under 300ms or over 1.700ms and conducted statistical analyses on the logarithm of RTs. In our analyses extreme values were also removed, however, they were calculated differently based on the standard deviation (for details, see below) and then the inverse transformation and not the logarithmic one has been applied to keep the analyses as parallel as possible in all our experiments including on the Russian data. Secondly, all mixed-effects linear regression models used in this study always included several predictors such as Trial Number of the target (the position of the item in the presentation list) and Reaction Time on the Previous Item which were apparently not included into the models by Jacob et al. (2017) to control for trial-level task effects and to keep the analyses across various experiments similar. In the following paragraphs, more information on data cleaning procedures and applied mixed-effects models will be provided.

Data cleaning was first carried out based on the accuracy rates of participants and other factors such as whether participants reported being able to notice and read primes. Similarly to Jacob et al. (2017) these criteria led to exclusion of 2 experimental items (semantic: *Schlips* 'tie'; orthographic: *Scheck* 'check') due to the low accuracy (below 70%) in the group of younger adults. To keep the analysis parallel, these items were removed from the further analysis in the group of older adults as well. None of the participants were excluded from the further analysis.

Further data cleaning included removal of all incorrect responses and timeouts (1.3% for the group of older adults and 3.48% for the group of younger adults). In order to normalize the distribution, we conducted analyses based on the transformed RTs (inverse transformation) and applied cutoff points to remove extreme values which were higher or lower than 2SD from the mean RT per participant. This has led to the removal of additional 4.6% of the remaining data for the older group, and 4.41% of the data for the control group of younger adults.

We analyzed RTs with mixed-effects linear regression models with crossed random effects for participants and items (see Baayen, Davidson, and Bates (2008)) using the languageR package (Baayen, 2008) and the lme4 package (Bates et al., 2014).

The model we fitted to the targets in the morphological set included Condition (Unrelated, Inflected, Derived, Identity) as a fixed effect. Condition was coded with successive differences contrasts, in which each level is compared to the previous one (inflected vs. unrelated, derived vs. inflected, and identity vs. derived) which allows establishing the presence of inflectional priming and comparing whether the magnitude of derivational priming is greater than that of inflectional priming. As predictor models included Trial Number (the position of the item in the presentation list; centered) to control for trial-level task effects, such as fatigue, Reaction time on the Previous Item (inverse transformed, centered), Word Form frequency of the target (centered) and Lemma frequency (centered). The control sets (orthographic and semantic) also included Condition (Identity, Related, Unrelated) as a fixed effect and the same predictors as for the morphological set.

Accuracy data were analyzed with generalized linear models with a binomial link function.

3.1.7 Results.

Table 16 presents mean accuracy rates, by-participant means, as well as standard deviations of RT data in each condition and in each set for groups of older and younger adults[16].

[16] The data for younger adults were provided by Jacob et al. (2017) for comparison purposes and were reanalyzed using the same procedures as applied to the data in all other experiments reported in the present doctoral dissertation. Therefore, the values reported here for the group of younger adults may differ from those originally reported by Jacob et al. (2017).

Table 16

Mean RTs, Standard Deviations and Mean Accuracy for Three Items Sets by Condition for Older and Younger Adults in the Experiment on German

	Morphological set							
	Older adults				**Younger adults**			
	identity	derived	inflected	unrelated	identity	derived	inflected	unrelated
RT	585.8	606.5	610.9	626.9	554.3	595.2	593,0	615,8
SD	130.5	126.3	131.0	111.8	131.3	141.2	129.3	145.3
Accuracy (%)	95.9	96.4	92.8	92.4	93.57	90.71	90.35	87.14

	Semantic set					
	Older adults			**Younger adults**		
	identity	related	unrelated	identity	related	unrelated
RT	566.4	595.3	601.5	544.0	579.7	581.5
SD	133.8	115.6	111.7	136.9	118.5	117.8
Accuracy (%)	94.1	94.8	91.0	92.66	94.51	91.93

	Orthographic set					
	Older adults			**Younger adults**		
	identity	related	unrelated	identity	related	unrelated
RT	556.7	604.7	612.5	528.9	582.1	584.3
SD	115.7	114.9	127.4	127.4	127.8	116.0
Accuracy (%)	97.49	91.6	94.33	94.66	91.61	94.83

Similarly to our analyses of Russian data we will mostly focus on the data from older adults while handling younger adults as a control group.

The accuracy analysis for the group of older adults revealed a trend toward more accurate responses after related derived primes than after inflected primes (β= 0.75, SD= 0.45, z-value= -

1.667, p=0095). In the control datasets, older adults were marginally more accurate after related than after unrelated primes (β= -0.731, SD= 0.39, z-value= -1.83, p=.066) in the semantic set and were significantly more accurate after identity primes than after related primes in the orthographic set (β= 1.344, SD= 0.502, z-value= 2.678, p=.007).

To examine the response patterns of older adults in more detail we fitted a mixed-effect model to the latency data from the morphological set. See Table 17 for the model.

Table 17

The Best-fit Model for the RT Data from the Morphological Set for the Older Participants in the Study on Processing of -ung Nouns and -t Participles

Random effects:		Variance	SD
Subject	Intercept	0.040901	0.20224
Item	Intercept	0.003653	0.06044
Residual		0.043800	0.20929
Fixed effects	Estimate	SE	t-value
Intercept	-1.704	0.03822	-44.58
Trial number	-0.0001616	0.00006134	-2.63
Length	0.0346	0.01438	2.41
Lemma frequency	-0.0001963	0.0001605	-1.22
RT on previous item	0.07642	0.03146	2.43
Effects of Condition			
Condition [inflection – unrel]	-0.05430	0.02064	-2.63
Condition [derivation – unrel]	-0.06352	0.02046	-3.10
Condition [derivation – inflection]	-0.009217	0.02046	-0.45
Condition [ident – inflection]	-0.08223	0.02049	-4.01
Condition [ident– derivation]	-0.07301	0.02021	-3.61

The results of the model indicate that for the group of older adults inflected items as well as derived items as primes yield significantly faster responses than unrelated items (t= -2.69 and t=-3.10 respectively). At the same time, there is no difference in response latencies following inflected and derived primes (t= -0.49) while derived items yield significantly slower responses than identity primes (t= -3.61). This pattern of results indicates the presence of facilitation for both inflected and derived items.

In order to make sure that reported priming effects cannot be attributed to orthographic overlap or semantic relatedness, we fitted a separate mixed effects model to both control sets (see Table 18).

Table 18

The Best-fit Model for the RT Data from the Orthographic and Semantic Sets for the Older Participants

		Semantic set			Orthographic set	
Random effects:		Variance	SD		Variance	SD
Subject	Intercept	0.052722	0.22961	Intercept	0.033101	0.18194
Item	Intercept	0.004321	0.06574	Intercept	0.004376	0.06615
Residual		0.043209	0.20787		0.050955	0.22573
Fixed effects	Estimate	SE	t-value	Estimate	SE	t-value
Intercept	-1.741	0.04503	-38.67	-1.702	0.03822	-44.52
Trial number	-0.000052	0.00007496	-0.69	0.00004109	0.00007778	0.53
Length	0.0522	0.01725	3.03	0.01476	0.01242	1.19
Lemma frequency	-0.000118	0.00008372	-1.41	0.0001052	0.0001948	0.54
RT on previous item	0.01777	0.03076	0.58	0.09961	0.02440	4.08
Effects of Condition						
Condition [unrel – rel]	0.02552	0.02016	1.27	0.005252	0.02175	0.24
Condition [ident – rel]	-0.1095	0.01999	-5.48	-0.1633	0.02175	-7.51

Analyses of the two control sets produced parallel results. Thus, the models revealed that the presentation of semantically or orthographically related items did not elicit significantly faster response latencies compared to unrelated items (t = 1.27 and t = 0.24, respectively) while both being significantly slower compared to identity condition (t = -5.48 and t = -7.51, respectively). Thus, unlike the morphological set we found no priming effects in the control sets which indicates the morphological nature of a facilitation effect observed in the morphological set obtained from older speakers of German.

3.1.7.1 Between group-comparisons.

To investigate whether the accuracy patterns found in the group of older adults differed from patterns found in the control group of younger adults the best-fit generalized linear model included the interaction between Age Group and Condition to a minimally different model without such an interaction. This comparison revealed that interaction does not significantly improve the model fit ($\chi 2(3) = 1.66$, $p = .64$).

However, the omnibus model of the error data revealed a main effect of the Age Group ($\beta = -0.597$, $SE = 0.189$, $z = -3.15$, $p < .001$), with older speakers showing overall higher accuracy rates than younger speakers (averaged across all conditions) in the morphological set. To further check the difference in error rates, they were compared only to the unrelated condition. This comparison also found a marginal effect of higher accuracy shown by older adults (β= -0.58, SD= 0.31, z-value= -1.847, p= .064).

The two age groups showed similar patterns in the control sets as well (in the orthographic set: $\chi 2(3) = 2.48$, $p = 0.289$; in the semantic set: $\chi 2(3) = 0.45$, $p = 0.796$). Thus, inclusion of the interaction parameter did not lead to the better model fit in neither set indicating similar effects for older and younger adults. There were no main effects of or interactions between Prime Type and Age Group for the orthographic or the semantic sets (all ps > .15).

Analogously, we also examined RT data in more detail by comparing an omnibus model for the morphological dataset including interaction between Condition and Age Group and a minimally different model with the interaction term removed similarly to our analysis of the accuracy data. A model comparison using the anova() function revealed that inclusion of the critical interaction did not significantly improve the fit of the model [$\chi 2(2) = 6.78$, $p = .079$].

It is worth noting, however, that the omnibus model surprisingly produced no evidence that older adults respond slower than younger adults as the main effect of Age was not statistically significant (β= -0.059, SD= 0.053, t= -1.10). The model also revealed the presence of significant interactions between Age Group and Condition (identity vs. derivation, identity vs. inflection) with t= -2.30 and t= -1.94, respectively. This indicates that the difference in RT after derived primes as well as with inflected primes compared to identity primes is significantly smaller for older than for younger adults. However, as previously found, reaction times to targets following both derived and inflected primes in each age group are still significantly slower than following identity primes and, hence, no full priming effect is elicited. Thus, this interaction does not reveal substantial differences in the morphological priming effects between groups of older and younger adults.

Releveling the model, the role of the Age factor on RTs in any of the four conditions was also examined and the only marginally significant difference between older and younger adults was observed for the identity condition ($t = 1.85$) whereas for all other conditions no effect of significant age-related slowing was observed (all ts < .85).

Similarly to the analysis of morphologically related items we also compared models with and without crucial interaction for control sets of semantically [$\chi2(3) = 3.37$, $p = .184$] and orthographically related [$\chi2(3) = 1.03$, $p = .594$] items. Thus, model comparisons revealed that adding an interaction of Age Group with Condition did not produce models with greater goodness of fit than the model without such interaction, showing similarities between two groups.

Separate models for younger adults are only presented in the study by Jacob et al. (2017). Our reanalysis of the data found only numerical differences and replicated the findings reported in the study by Jacob et al. (2017).

Overall, the comparisons indicate similar patterns with regard to response latencies and priming effects for both age groups as well as significantly higher accuracy rates of older speakers.

3.1.8 Discussion.

The reported experiment examined processing of -t participles and -ung nominalizations in German. The design of the experiment allowed to directly compare processing of derivation and inflection while using the same target. The results from the experiment on older adults show no statistical difference in processing of derived and inflected words while reaction times after derived primes are significantly slower than after identity primes. At the same time response latencies after inflected and derived primes are statistically faster than after unrelated primes. In essence, we observe a partial priming for derived as well as regularly inflected words. Crucially, this effect is not attributable to the mere orthographic overlap or semantic relatedness as we found no priming effects in two control sets. The results from the control set of data obtained from the group of younger adults reported by Jacob et al. (2017) show similar patterns.

Crucially, the response patterns of older and younger adults are similar showing no difference in processing of inflected or derived words with partial priming effects for both types. This indicates that processing mechanisms of regular inflected and derived words in the group of healthy older adults are resistant to possible effects of ageing and remain fully intact. These findings are reminiscent of findings from Hebrew by Kavé and Levy (2004) and Spanish by Duñabeitia et al. (2009) which also demonstrate that the ability to segment morphologically complex words is preserved in older adults. Furthermore, our findings are also compatible with the data reported by

Clahsen and Reifegerste (2017), since processing of regularly inflected forms was demonstrated by Clahsen and Reifegerste (2017) to be not affected in older adults. The only clear effect in our experiment is the higher accuracy shown by older adults.

Similarly to our findings on processing of morphologically complex words in Russian, these results do not support a claim of speed-accuracy tradeoff as proposed, for example, by Ramscar et al. (2014). However, instead of the global effect of slowing which was observed in the older native speakers of Russian, older native speakers of German show a higher accuracy rate than younger adults while being equally fast. Once again, these data show that general slowing and higher accuracy do not necessarily correlate with each other and, hence, run against the predictions of the simulation models by Ramscar et al. (2014). Thus, "a picture in which an improvement in one dimension – accuracy – is shown to come at a cost in another, speed" (Ramscar et al., 2013, p. 36) may not be always true.

The claim by Ramscar et al. (2013) presumes that younger speakers might have a smaller vocabulary and thus lexical decision experiments might be perceived as including a higher ratio of non-words than existing words. Real words would be thus more obvious and easier to respond to for younger adults than for older adults. This easiness would be responsible for faster reaction times to the spotted real words as well as the lower accuracy of younger adults as they would classify some existing words as non-words. However, the present experiment shows that higher accuracy might not necessarily lead to slower reaction times with advancing age.

In the present experiment on German we observed a facilitation for derived words in the group of older adults similarly to the experiment on Russian. The reported results resemble the findings from numerous studies (Clahsen & Neubauer, 2010; Clahsen et al., 2003; Jacob et al., 2017). This priming effect could be attributed to the nature of the derived words which are considered to maintain their morphological structure.

Facilitation effects in masked priming experiments are often interpreted in favor of the affix-stripping mechanism except for the cases such as *fall-fell* when decomposition into constituents is impossible (Crepaldi et al., 2010) or L2 processing which is thought to rely less on decomposition-based processing (Jacob et al., 2017; Kırkıcı & Clahsen, 2013). Alternatively, it has been suggested that a morphological priming for derived words may be lexically mediated since derivation produces new lexical entries (Kırkıcı & Clahsen, 2013). The results of the present experiment do not show any differences in the group of older adults concerning processing of -t participles and -ung derivation in terms of the amount of priming and its type (a partial priming effect). It may indicate identical access mechanisms responsible for processing of derived and inflected forms as we found no clear evidence showing the influence of the lifelong experience or decline of the declarative memory which could have influenced morpho-lexical processing of derived words more than morpho-syntactic processing of the inflected forms.

Studies by Jacob et al. (2017) as well as Kırkıcı and Clahsen (2013) show that under certain conditions, for example, when tested populations are disadvantaged compared to healthy young native speakers as, for example, L2 speakers, linguistic differences between derived and inflected forms could translate into differences in experimental results. Therefore, the comparison of facilitation effects for derived and inflected words is theoretically important as it could identify the conditions under which the difference between processing of inflected and derived words becomes salient.

The present experiment indicates that the difference in processing derived and inflected forms may be restricted to language learners even though more studies are clearly needed to examine processing mechanisms in other "challenged" groups such as older adults since absence of the difference in the current study does not exclude the existence of such differences. However, the most likely explanation for the current results is the processing of derived and inflected words by means of the robust decomposition-based parsing mechanism.

3.2 Experiment II. Processing of German Plural Nouns

3.2.1 Processing of plural -er and -s forms in German. Introduction.

While the experiment presented in the previous chapters focused on processing of derived -ung nouns and -t participles in German and on the comparison between morpho-syntactic processing of inflected words and morpho-lexical processing of derived words, the present one investigates the contrast between irregular and regular (default) inflected forms in German.

This contrast is of great theoretical value since it allows us to investigate whether there is a contrast between forms which are supposedly lexically stored and those which are combinatorial rule-based units and thus it also allows us to uncover the key properties of the mental lexicon. This contrast has not been examined before using the masked priming experiment which enables us to tap into the access representations which are usually assumed to be processed by the highly automatized parsing mechanism. This mechanism is posited to be robust and efficient and to act regardless of the properties of the particular language or morphological structure of the word itself as, for example, in the case of the pseudo-derived words such as *corner* in English. The experiment presented in the next chapter puts the said mechanism to the test in German with regard to processing combinatorial and lexically stored plural forms.

Furthermore, we focus on the processing of combinatorial and lexically stored plural forms by older adults as effects of ageing on mechanisms employed during recognition of such forms remain unclear. At the same time studies of other special groups such as language learners, for example have illustrated, it is precisely these groups that might be more sensitive to the linguistic contrasts (Jacob et al., 2013; Kırkıcı & Clahsen, 2013). With regard to the plural forms, it might be possible, for example, that lexical access mechanisms which may be more involved in processing -er forms may be more affected by age-related changes than robust combinatorial rule-based in case of -s plurals.

Thus, the experiment presented in the next chapters will assess the claims regarding the contrast between lexically stored and rule-based forms and will examine the influence of the ageing on the proposed processing mechanisms. However, before we address these issues, it is necessary to discuss the properties of the plural system in German in greater detail.

3.2.1.1 A linguistic description.

Plural formation in German is much more complicated than plural formation in, for example, English so that there used to be claims as mentioned Wiese (2000, p. 142) that it is “not rule-governed and defies formal description”. However, as numerous recent studies have demonstrated, this is far from being true, even though these rules are not easily captured and often include dozens of exceptions (Bittner & Köpcke, 2016; Gaeta, 2008; Köpcke, 1988; Wegener, 1999, 2004; Wiese, 2000, 2009; Wunderlich, 1999). The complexity of the problem could be illustrated by the fact that even the number of plural morphemes in German remains a highly controversial issue. It varies from 9, including determiners as listed by Köpcke (1988) and 5 in Gaeta (2007, 2008) and Wiese (2009) down to only 3 as suggested by Wegener (1999). This is partially due to the status of umlaut (vowel fronting) in plural formation and the question whether it should be treated on its own as a plural marker (plus its combinations with other plural affixes) or not.

I will start an overview by presenting the plural system in German as done by Köpcke (1988) and Bittner & Köpcke (2016). Thus, Köpcke (1988, p. 307) identifies 9 plural markers including -e (e.g *Fish* ‘fish’ - *Fische*), -(e)n (e.g., *Auge* ‘eye’ - *Auge*), -er (e.g., *Geist* ‘ghost’ - *Geister*), -s (e.g., *Auto* ‘car’ - *Autos*), -Ø (e.g., *Fenster* ‘window’ - *Fenster*), umlaut (e.g., *Bruder* ‘brother’ – *Brüder*), umlaut + -e (e.g., *Kuh* ‘cow’ - *Kühe*), umlaut+ -er (e.g., *Wald* ‘wood’ – *Wälder*), definite article (i.e., *die*). He states that the first 4 plural markers are suffixes and the 5th

should be treated as a zero morpheme and is phonetically zero. The umlaut can occur only in some cases, for example, with -e and -er affixes but not with –(e)n. Köpcke (1988) lists several criteria which influence the choice of the plural marker in German including the type of the derivation affix, the final consonant or vowel of the stem, the prefix of the stem vowel, the mutability of the stem vowel (i.e., the possibility of umlaut), the gender of the noun as well as its animacy.

With regard to the number of affixes, it has been claimed that zero-affix should not count as a separate affix, as there is a complementary distribution between final -e (schwa) and zero ending and thus it is completely predictable (Wegener, 1999). Wiese (2009, p. 139) proposes the following rule to describe the distribution of -e (the written equivalent of final schwa) and zero: "the suffix -e occurs after a stressed syllable, while '0' is only found after a stressless syllable, a so-called "reduced" or "schwa syllable", i.e., one which ends in either an unstressed vowel or a syllabic (sonorant) consonant". Thus, the number of affixes could be reduced to only four including –(e)n, -e, -er and -s. Taking into account that umlaut is also absolutely predictable for -er plural forms, there is no need to introduce an additional umlaut + -er pattern as done by Köpcke (1988). Instead, one might end up with four morphemes and five plural forms (for -e affix there are two forms: one without umlaut and one with) in total as proposed by Wegener (1999).

Recently Wiese (2009) argued against treating -e (final schwa) as a morpheme as its appearance is predicted on the basis of phonological constraints. In essence, -e is inserted due to the prosodic requirements in order to "create a final sequence of a stressed and a reduced syllable" (Wiese, 2009, p. 144). Moreover, this requirement is also seen in case of the -er plural affix which is applied according to Wiese (2009) to a lexicalized class of only monosyllabic nouns. Thus there are only three plural affixes and namely -n, -r and -s.

It has been noted that masculine and neuter nouns often behave similarly with regard to plural formation in contrast to feminine nouns. Approaches, which include -e and zero endings in their classification, make use of this contrast and suggest a hierarchy of affixes with some affixes being treated as irregular ones (i.e., -er, -(e)$n_{masc/neuter.}$,-e_{fem}, -$Ø_{fem}$) other as sub-regular (i.e., -(e)$n_{fem,}$ -$e_{masc/neuter}$, -$Ø_{masc}$) ones and yet another type as a default one (i.e., -s) (see Wiese (2000)). This classification is mainly based on productivity as noted by Wiese (2009). The irregular affixes are unproductive affixes, while -s is considered to be default due to its productivity and application to various "non-canonical" words such as proper names, loanwords (non-integrated), abbreviations etc. However, this classification remains problematic as it is sometimes not clear, what patterns should be classified as productive (e.g., pl. *Computer* with zero ending or *der Remix/die Remixe, der Boss/die Bosse* with -$e_{masc./neuter.}$ type).

The classification by Wiese (2000) associates three plural types mentioned above with three levels (or strata) in the lexicon which are defined by various types of morphological rules. *Regular* affixes such as -s and -en_{fem} are defined by abstract rules which apply to different levels (level 3 and level 2 respectively) of the lexicon. For example, in case of -s plural form the rule could be represented in the following way: Insert /s/ in $\left[\begin{bmatrix}+N\\-V\end{bmatrix}\underline{\qquad\quad}\right]_{\{+\text{ plural}\}}$. The rule for -$en_{fem}$ plural is rather similar though it additionally specifies the +fem feature and requires an unmarked foot (Wiese, 2000, p. 139). These rules are regular in the sense that no lexical listings are required. The *irregular* level 1 affixes may also have some rules describing their application but they are more specific and require lexical listings such as: Insert /r/ in $[\ N_a \underline{\quad}]_{\{+\text{ plural}\}}$ for N_a = {*Buch, Wurm, + tum*, ….}.

The assumption of three levels also reflects some other morphological and phonological properties. Wiese (2000) provides the following examples to demonstrate the differences. Whereas level 2 and level 1 affixes may precede the derivational suffix -schaft, -s plural cannot (e.g., *Student-en-schaft*, *Völk-er-schaft* or *Ärzt-e-schaft*). Similar ideas regarding the tripartite structure of the plural system with differences between irregular, (sub)-regular and default plural markers which could be also expressed in terms of lexical storage, minor rules and major rules have been suggested in other studies as well (Dressler, 1999; Wiese, 1999; Wunderlich, 1999). Eisenberg (2013) identifies marked and unmarked affixes (e.g., -er as marked for neuter nouns in contrast to -e for masculine/neuter nouns) for each gender and the default -s affix.

Note that the major accounts usually select similar plural markers as unmarked or sub-regular, namely -en_{fem} and -e_{nonfem}. These affixes together with -$en_{masc.}$and -$e_{femin.}$ are often referred to as the "core plural system" (Eisenberg, 2013; Wiese, 2009). This term reflects the overall frequency distribution of plural markers in German, as they dominate the German plural system in terms of type frequency (80.4%) and token frequency (86.2%) (Gaeta, 2008). If one considers complementary distribution of -e and zero ending these numbers would be even higher, as, for instance, the zero ending has a type frequency of 33.8% for masculine and neuter nouns. Certain plural markers and especially –(e)n for could be considered gender specific as it occurs in 97% of all plural forms derived from feminine nouns. Considering its productivity, -en_{fem} could be treated as a default affix for feminine nouns in German (Gaeta, 2008).

Marcus et al. (1995) argue that -s plural is default in German and list several criteria in support of their claims. The application of -s is morpho-phonologically free as it occurs in contexts which disallow the application of other plural affixes, whereas other affixes appear only under particular conditions such as the gender of the singular forms and their syllabic structure, as, for example, is the case of -er plurals. The -s affix applies to all uncanonical words and borrowings such as *Café*, *Kiosk* or *Handy*. Furthermore, -s is also applied to onomatopoeic nouns (*Kuckucks* 'cuckoo'), quotations, acronyms (*GmbHs* 'corporations'), truncations (*Wessis* 'West Germans'), to surnames (*Schröders*), nominalization of conjunctions (*Wenns*), verbal phrases used as nouns (*Rührmichnichtans* 'touch-me-nots'). These examples demonstrate that the -s affix in German is an "emergency" plural and is rule-based since under precisely these conditions memory patterns are not accessed (Marcus et al., 1995). As Eisenberg (2013) also argues -s is different from other plural affixes as there is a requirement for plural forms of morphologically simple nouns to form a trochee which is usually followed in all cases except for -s plurals.

This interpretation of the -s affix in German is not the only possible one. Wegener (1999) claims that for highly marked words such as onomatopoeic nouns, surnames, quotations and borrowed words -s is preferred as it allows the preservation of the morpheme boundary which is violated in the case of the other affixes, for example, *Termin*. - *Termi.ne* or *Villa* - *Vill.en*). Wegener (2004) defends the view that -s plural can be explained functionally in all cases and therefore is not a default. However, it is not clear why the functional explanation provided by Wegener (2004) would preclude the interpretation of the -s affix as a default one as postulated by Marcus et al. (1995) in contrast to other forms. Some of these might be also rule-based as -en_{fem} but are class-specific (Sonnenstuhl & Huth, 2002).

The linguistic description of the plural system in German and possible defaultness of the -s plural bears direct relevance to the psycholinguistic theories of processing and representations of the plural forms. As previously hinted at, some theories distinguish between default and, hence, rule-based -s plurals and other plurals which are considered to be irregular and, hence, lexically stored (Clahsen, 1999a; Marcus et al., 1995). In light of the descriptions of -en_{fem} as being regular as well, it was admitted that "nothing in the dual-mechanism account prevents us from assuming more than one rule per inflectional category" (Clahsen, 1999b, p. 1047). What is seen as the core of the theory is the contrast between items stored in the lexicon and those defined by means of symbolic operations. To account for the difference between -en_{fem} and truly irregular forms such as -er it was hypothesized that even though both forms are stored only -en$_{fem}$ preserve their internal morphological structure while -er forms are stored as frozen forms (Lück, Hahne, & Clahsen, 2006).

A different view is proposed by Bittner and Köpcke (2016) and Köpcke (1988, 1998) who suggest a schema-based approach. Creation of plural forms occurs via matching a particular abstract schema in the mental lexicon. The schemas have a prototype structure and the strength of the schema is defined by the strength of its components such as affixes “which is in turn determined by salience, frequency, and cue validity of these components” (Köpcke, 1988, p. 305). Köpcke (1988) understands salience as acoustic prominence while cue validity refers to the distinctiveness of the marker. For instance, the -s affix is assumed to have high cue validity as there are few singular nouns which end in the -s, in contrast to -er. This contrast should be reflected in experimental findings. With regard to the recent loanwords, this usage-based approach predicts that -s forms should be eventually substituted with –(e)n in recent (feminine) loanwords, as –(e)n is considered to have the overall highest cue strength due to its high cue validity, salience and high type frequency.

The model by Köpcke (1988) is a usage-based model and, hence, production of plural forms is probability-based as it takes several factors such as type frequency, salience and cue validity into account. There is no dichotomy between rule-based formation and irregular forms but rather a difference in the degree of schema abstractness. The most abstract schemata rely on such notions as the word class or gender and do not depend on the lexical properties of particular items. The more abstract the schema is, the more productive it is which could result in a default schema. In this respect, Bittner and Köpcke (2016) treat -en as a default schema as it is based on the very simple distinction [± FEM].

In the next chapter I will review the most recent experimental studies which examine the plural system in German and usually try to either support or disconfirm the assumptions of the dual-route treating -s plural as a default marker in contrast to all other affixes. Furthermore, while the status of some markers such as -en$_{fem}$ remains controversial, there appears to be a consensus regarding irregularity of -er forms investigated in the present study. The studies presented below examine the implications of such views for the mechanisms of processing and representations of plural forms in German.

3.2.2 Previous experimental studies on German plural nouns.

In this chapter we will review the recent experimental findings from studies on processing of plural noun forms in German which try to establish whether a predicted dichotomy between -s plural forms and other markers indeed exists.

One of the studies which suggested clear difference in processing of regular -s and irregular -er plural forms by means of a priming study was conducted by Sonnenstuhl et al. (1999). For detailed information regarding materials of the study one should refer to the chapter 3.2.5 as the present experiment uses the same critical items as in the experiment by Sonnenstuhl et al. (1999). They have conducted a cross-modal priming study and assumed that if regular -s nouns are decomposed into constituents during processing, they should produce full priming effects, whereas if irregular -er nouns are stored as separate lexical entries, only indirect activation would be expected. Indeed, clear difference between a full priming effect for -s nouns and a partial priming effect for -er nouns has been found which has been interpreted as evidence in favor of the dual mechanism perspective.

Continuing investigation of plural nouns in German, Reifegerste al. (2017) conducted an unprimed lexical decision experiment examining the processing of several plural affixes -er, -e, -en forms in German as well as the role of number dominance. Singular-dominant words are the words which are more often used in their singular form (e.g., *mouth* or *parlour*), whereas plural-dominant forms are the ones which are normally referred to in plural forms (e.g., *peas, guts*).

The question is how fast the plural-dominant forms are processed compared to other forms and consequently whether such forms are stored in the memory or decomposed (followed by the recombination stage). The patterns may also differ depending on whether plural forms are regular or not. For example, according to Reifegerste et al. (2017) the dual-route model would predict decomposition of only regular plural forms regardless of the number dominance (e.g., *peas* as well as *brides*), whereas other forms should be stored and, hence, lead to faster reaction times upon presentation of more frequent forms (i.e., plural forms of plural-dominant nouns compared to the single-dominant nous). Furthermore, the authors examined whether the response patterns change with advancing age as “the likelihood that inflected words, even regular ones, are recognized via storage may increase with age” (Reifegerste et al., 2017, p. 474).

The results were in line with the previous findings showing differences between two age groups of German speakers which showed differences with regard to the effect of number dominance. Whereas there was no effect of number dominance for younger speakers with overall slower response latencies for plural forms, older people showed an effect of dominance for plural nouns. Reifegerste et al. (2017) interpreted the findings as indicating decomposition of plural nouns by younger native speakers of German, whereas older adults appear to rely more on storage-based mechanisms. It was hypothesized to be a possible effect of 40 years of experience of older German adults with complex inflected forms seems which may have shifted processing mechanism towards whole-word access. Importantly, Reifegerste et al. (2017) failed to find any effect of the affix type.

Support for the dual-route model mechanism of processing regular and irregular plurals in German often comes from aphasic patients. Lorenz and Biedermann (2015) examined processing of plural nouns in German by two patients diagnosed with non-fluent aphasia following ischemic strokes in the fronto-parietal area of the left hemisphere. The researchers employed the picture naming task as well as the elicitation task to examine the production of plural nouns. Their set included regular -s plural nouns which were considered to be default in German, irregular -e and -er plural nouns and fully predictable nouns with the -n suffix in plural, which applies to feminine nouns that end with schwa in singular.

Lorenz and Biedermann (2015) found that one of two patients had significant difficulties with -s plural nouns in both tasks such that, for example, in the elicitation task no single plural -s form has been produced. His performance in production of other forms was better. The authors argue that these results fit the dual-route model which proposes rule-based processing of the -s plurals. The authors also note that only difficulties at the word-form level could cause the specific impairment in production of -s plural nouns since the conceptual-semantic feature “multiple” was clearly available, whereas the form information and namely -s affix was not. It was assumed that findings indicate decomposition-based processing of -s forms and a full listing of all other forms which is consistent with the hypotheses of the dual-route models.

However, the status of -s plural affix remains a hotly debated topic. For instance, a recent study by Zaretsky and Lange (2017) who used a written production task asking 585 participants to produce plural forms from the nonce-words failed to observe any evidence in favor of the default status of -s morpheme. They used the same non-words as in the study by Marcus et al. (1995) which were divided into rhymes and non-rhymes. Whereas rhymes were supposed to elicit associations with existing words (e.g., *Pind – Pinder* resembling *Kind* ‘a child’ – *Kinder* ‘children’), non-rhymes had no such phonotactic analogies. The study tried to replicate the findings from Marcus et al. (1995) which showed that the -s plural affix “obtained the highest plausibility values in comparison with other plural markers in the unusual language material: nonce nouns having no rhymes in Modern High German as well as nonce nouns presented as names and borrowings” (Zaretsky & Lange, 2017, p. 155). The original study was criticized on statistical grounds, such as a lack of power due to only 48 participants being included, quality of the data and the statistical analysis (e.g., whether the data was normally distributed and *z*-transformed etc.).

Zaretsky and Lange (2017) having tested more participants (585 vs. 48) and having applied a variety of statistical methods (categorical regressions, binary logistic regressions such as -s vs. other affixes etc.) found no evidence in favor of the default status of the -s affix in German. The -s affix was used in 16% of plural forms with non-rhymes and only in 8% with rhymes which is much less than it presumably should have been considering the favorable experimental conditions for the application of the default pattern, that is absence of any precomputed form. The default pattern should by definition be applied "to any item whatsoever, as long as it does not already have a precomputed output listed for it" (Marcus et al., 1995, p. 192) and thus should be according to the authors applied much more often than other patterns under given circumstances.

Note though that the study Zaretsky and Lange (2017) actually does not provide any convincing evidence against the default status of the -s affix in German. First, it still generalizes to novel items independently of phonological similarity and its productivity is substantially higher than expected considering its overall distribution around 2-4% in German. Second, the default status of -s is supported by other criteria which include among others application to novel words, quotations, surnames, truncations, nominalizations of VPs, borrowings etc. (Bartke, Rösler, Streb, & Wiese, 2005; Marcus et al., 1995). Third, the productivity of other affixes tends to reflect their type frequency in German and thus might be simply analogy- or frequency-driven rather than rule-based. Thus, the chosen experimental task might not be well suited enough for clearly showing the distinction between default and non-default patterns as it reflects the frequency distribution observed in German in contrast to the task employed by Marcus et al. (1995) which relied on plausibility values and thus allowed the participants to directly compare all competing affixes and choose the most appropriate one (Clahsen, personal communication).

Moreover, as it was hypothesized by Clahsen (1999b) and later experimentally examined by Sonnenstuhl and Huth (2002) not only default inflectional patterns could be regular as some non-default plural affixes could be considered to be rule-based and in this sense regular as well. Sonnenstuhl and Huth (2002) have conducted an unprimed lexical decision task and found no frequency effect for -s forms in contrast to frequency effects for completely predictable –n plural forms from feminine nouns ending in schwa (e.g., *Blume* 'flower' – *Blumen* 'flowers') as well as for -n plural forms from neuter or masculine nouns where it is not predictable (e.g., *Muskel* 'muscle' – *Muskeln* 'muscles') and -er plural forms. At the same time, the cross-modal priming experiment has shown that predictable –n plural forms patterned similarly to -s forms yielded a robust priming effect. Surface frequency effects in the simple lexical decision experiment were interpreted as indicating availability of full-form representations. At the same time robust priming effects for -s and predictable -n forms were interpreted as showing the prime's decomposition into stem and affix in contrast to reduced priming effects for unpredictable -n forms (and also irregular -er forms tested as well). To sum these findings up, predictable -n forms showed similar effects as irregular forms in the unprimed lexical decision experiment and resembled -s forms in the cross-modal priming experiment.

Sonnenstuhl and Huth (2002) suggested to distinguish between modality-specific access level representations and modality-independent central level entries. Full-form access representations are not available for default forms in contrast to all other forms and hence, no surface frequency effects were found for -s forms in the unprimed lexical decision experiment. However, non-default $-en_{fem}$ is a fully predictable class-specifc affix in German and therefore could be considered to be rule-based. Accordingly, no full-form entry for $-en_{fem}$ forms should exist in the lexicon and hence, these forms are decomposed first and will then activate their lexical entries for stem and affix (Sonnenstuhl & Huth, 2002). These findings allow to distinguish between regular default forms, class-specific inflection and irregular forms with regard to German plural inflection.

Along the same lines, an ERP study by Bartke et al. (2005) has shown that -e plural (labelled as subregular) nouns are treated differently from truly irregular nouns as shown by reduced N400. Somewhat unexpectedly an analysis which separately treated $-n^{fem}$ and $-n^{nonfem}$ nouns has not shown any differences. Nevertheless, based on the findings for -e plural nouns the authors also advocate for a revision of the dual-route model. In addition to the default component and storage-based component they propose a third rule-guided component to account for the observed behavior of the subregular plural patterns.

An alternative account which also argues that the distinction between rule-based forms and unstructured lexical entries may be not enough to account for the properties of the German plural system was proposed by Lück, Hahne, and Clahsen (2006). The researches have also conducted an ERP experiment having presented correctly and incorrectly inflected plural nouns. The authors reported LAN negativity for plural forms with -s indicating their combinatorial nature. In contrast, a lexical violation effect N400 was found for -n plurals showing that such forms constitute a lexical entry. However, a LAN effect was found for -n plural forms was found as well showing that these items also have internal morphological structure. This is arguably due to the properties of -n plural marker which is predictable for feminine nouns ending in schwa.

Lück et al. (2006) refer to the three-way distinction for morphologically complex words proposed by Anderson (1992) and Aronoff (1994). The posited distinction is between combinatorial forms as a result of the productive inflectional rules, combinatorial entries such as derived words "resulting from rules that define complex internally structured lexical entries" (Lück et al., 2006, p. 145) and frozen entries such as irregular forms (e.g., *swam*) which are stored unstructured as whole words. Essentially, -n_{fem} forms are then treated as combinatorial entries with internal morphological structure similarly to derived words.

The differences observed in the experiments may be partially due to the differences in methods used since, for example, priming methods are designed to examine online processing mechanisms in contrast to more metalinguistic tasks such as conscious production of forms from nonwords. Furthermore, some effects may be modality specific as well. For instance, Lück et al. (2006) observed the LAN effects for -n plural forms only in the auditory ERP priming which were absent in the visual ERP experiment by Weyerts, Penke, Dohrn, Clahsen, and Münte (1997). This was explained as being due to the fact that a morphological structure may play a more important role when words are presented in auditory modality. The signals are processed in a linear way, that is as they unfold in time, possibly leading to an early identification of the stem followed by an affix whereas in visual modality the word is immediately available and participants pay more attention to its lexical status.

With regard to the difference between -er and -s plural forms, a cross-modal priming experiment has shown robust differences in facilitation effects (Sonnenstuhl et al., 1999). However, there have been no masked priming studies which tap into access level representations which we attempt to address. As mentioned earlier, the observed differences in priming effects could be modality specific and no difference might emerge if primes are presented visually and the participants are not consciously aware of the primes. If one takes into account the often posited early morpho-orthographic processing and blind decomposition mechanism, both -s and -er plural forms should be easily equally easy decomposed into their morphological constituents.

Furthermore, it is also not clear until now whether processing mechanisms and the mental representations posited for younger speakers of German change with advancing age as there is essentially only one study which has addressed this issue, that is by Reifegerste et al. (2017). Unfortunately, this study has performed the analysis across all types of plural nouns and the authors have excluded -s plural nouns from the final analysis, which leaves the question regarding processing of such nouns in older adults open.

The possible age-related changes may depend on the assumed nature of the -er plural forms. Consider, for example, the following possibility. As mentioned by Lück et al. (2006) certain plural affixes could be treated as combinatorial entries which are morphologically structured in contrast to truly irregular forms such as, for example, *sang* in English which are treated as frozen entries. However, the claim by Lück et al. (2006) and Clahsen (2006) refers exclusively to the fully predictable feminine nouns with a stem-final schwa -n affix "whereas all other -n plurals are suppletive" (Clahsen, 2006, p. 9). This would mean that plural forms such as *Kinder* 'children' are not decomposable and essentially should behave similarly to *fall-fell.* In this case the facilitation effect might arise through lexically-mediated processing which may change for example due to the "greater age and, thus, greater experience with complex forms facilitates storage-based access" (Reifegerste et al., 2017, p. 485) and this would also lead to larger facilitation effects for such forms in older adults. Alternatively, the priming effect may decrease as a result of the decline of the declarative memory and as hypothesized by Clahsen and Reifegerste (2017) weaker memory links between stems leading to less facilitation.

Furthermore, an interesting hypothesis has been recently proposed by Aronoff et al. (2016) who claimed that even such robust effects as an early automatic decomposition which is presumably responsible for *corner – corn* priming effects in English may be language specific. This effect may depend on the salience of the affix reflecting the particular properties of the spelling system which either more or less consistently distinguishes affixes from homophonous final letter sequences of the monomorphemic words with substantial differences between English and German. Aronoff et al. (2016) illustrate this difference in the following manner. For example, final /s/ in English spelt as -s almost always marks either the noun plurality or 3rd Sg. on verbs, whereas in written English in monomorphemic words it almost never occurs in this position which is in contrast to hundreds of words that end with /s/ phonologically, such as *since, tense* etc. Thus English reserves the final -s almost exclusively for affixes only. Aronoff et al. (2016) claim the German writing system encodes this distinction between monomorphemic words and morphologically complex words much less consistently because, for example, -er in Geman could be not only the plural affix or the derivational one (e.g., *Bäcker* 'baker') but also in a large number of monomorphemic words (e.g., *Finger* 'finger' or *Zimmer* 'room'). Owing to this reason, it could be the case that the parsing mechanism in German would not necessarily be blind to the same extent as in English and would take into account the structure of the morphological representations.

Furthermore, the results of the studies used to argue in favor of the blind morphological decomposition even in English, might not be entirely reliable. For instance, Baayen et al. (2011) considered the study by Rastle et al. (2004) to be problematic since among the pseudo-derived words such as *corner* it also included the words such as *fruitless*. The word *fruitless* could be found in expressions even in its literal meaning such as *fruitless tree.* In other cases the affixes still expressed their regular meaning even if the base is no longer clearly detectable (as in *archer* or *early*).

Considering the reasons mentioned above, it is possible that the results of the masked priming experiment in German could reflect the differences, for example, between -s and -er plurals in line with Sonnenstuhl et al. (1999) and Sonnenstuhl and Huth (2002) as both forms may not be necessarily be automatically decomposed as expected according to the affix stripping mechanism.

The experiment reported below will focus on processing of -s and -er plural forms in German and examine whether differences between -er and -s plural forms are restricted to lexical representations (e.g., as shown by cross-modal priming studies) or are present already on the access level. This will also allow us to look at the processing mechanisms of the access level representations from a cross-linguistic perspective as well as to assess the claims that previously reported blind decomposition effects may be a property of only some languages such as English or French, but not others such as German.

The main focus, however, of our experiment is to explore effects of ageing on processing of rule-based and lexically-stored inflected forms in German and to establish whether such effects exist, whether they are language-specific and limited to particular linguistic phenomena (e.g., processing of irregular forms which may rely on storage-based mechanisms of recognition) or consist only in slower response latencies and/or higher accuracy rates with advancing age. In our experiment presented below we will address these questions.

3.2.3 Participants.

32 older native speakers of German and 37 younger native speakers of German took part in the experiment. All participants differed from those tested by Sonnenstuhl et al. (1999). Recruited participants were living in Germany at the time of testing, had normal or corrected-to-normal vision and hearing, gave their informed consent, and were paid for their participation in the study had no history of neurological or language-related impairments, had normal or corrected-to-normal vision and hearing (see Table 19 for demographic details on all participants).

Table 19

Demographic Information on Participants in the Study on -s and -er Plural Forms in German

	Older group			Younger group		
Number	32			37		
Sex	5 males, 27 females			13 males, 24 females		
	mean	SD	range	mean	SD	range
Age	67.7	10.1	52-84	27.2	4.4	19-38
CERAD	85.3	9.5	69-96	-	-	-
MMSE	29.09	1.2	27-30	-	-	-

As in other reported experiments, all older adults completed the neuropsychological test battery of the Consortium to Establish a Registry for Alzheimer's Disease (CERAD-Plus; www.memoryclinic.ch). The CERAD composite score (Chandler et al., 2005) is the sum of several tests and include the participant's score for Verbal Fluency (Animal Naming), the modified Boston Naming Test, Constructional Praxis as well as Word List Learning, Recall, and Recognition Discriminability. It was possible to obtain 100 points.

From the group of the older adults three participants had to be removed prior to any further analysis. One participant was excluded due to the diagnosis of the paranoid schizophrenia and two participants were removed due to the somewhat low composite CERAD score (63 and 66) which was below 1.5 SDs from the population mean as calculated according to the formula reported by Berres et al. (2000) for the German translation of the CERAD neuropsychological battery. The ratings of cognitive performance from other participants show a pattern indicative of healthy cognitive ageing[17].

Thus, the total number of older participants included into further analysis was 29.

[17] Inclusion of the participants removed based on the composite CERAD score has not changed any of the effects reported in the next chapters.

3.2.4 Procedure.

The experimental procedure of this experiment was completely identical to other masked-priming experiments conducted as part of the current Ph.D. project. For details refer to the description provided in the Chapter 3.1.4 Procedure.

The experiment lasted approximately 20-25 minutes.

3.2.5 Design and predictions.

The experimental materials of our study are based on the cross-modal priming study on German plurals by Sonnenstuhl et al. (1999). The experiment included 30 nouns that take -s plurals and 30 nouns with irregular -er plural forms. All target words were stem (singular) nouns forms, for example, *Nest* 'nest' preceded by three types of primes: either (i) an identity prime, (ii) the plural form (e.g., *Nester* 'nests'), or (iii) an unrelated prime (e.g., *Satire* 'satire') from Sonnenstuhl et al. (1999).

The information on frequency value, number of letters and syllables is presented in the Table 20.

Table 20

Length and Frequency Information for Tested -er and -s Plural Forms in German

		Lemma frequency (per million)	Word frequency (per million)	Letter length	Syllable lenght
-s plurals	Control	4.8	2.6	7.3	2.4
	Test	6.8	2.5	6.8	2.4
	Target	6.8	4.3	5.8	2.4
-er plurals	Control	24.8	21.5	7.4	2.5
	Test	83	24.6	6.7	2.2
	Target	83	46.4	4.7	1.2

The lemma frequencies of the nouns used in the study differed significantly (CELEX lemma frequencies of -er nouns: 83.2 vs. 6.8 for -s plurals; $t(29)= 2.04$, $p= 0.025$)) which, as Sonnenstuhl et al. (1999) noted, follows a general pattern in German with higher frequencies for nouns that take -er plurals compared to much lower frequencies of nouns that take -s. The same applies to the surface frequency (t(29)= 2.04, *p*= 0.024). On the other hand, nouns taking -s plurals are significantly longer than nouns taking -er plural forms in terms of number of letters (t(58)= 2.001, *p*= 0.16) and have more syllables (t(56)= 2.001, *p*< 0.001). Note, however, that priming effects are examined within sets and not between such that these differences should not directly affect them.[18]

As for the matching within sets, there was no difference in terms of the length in letters, number of syllables, surface frequency and lemma frequency between related and unrelated primes in the group of -s nouns (all *p*s> 0.15). Regarding -er nouns, related und unrelated primes selected by Sonnenstuhl et al. (1999) and used in this experiment did not differ in surface frequency (t(57)= 2, *p*= 0.83), but marginally differed in the number of letters (t(52)= 2, *p*= 0.061), in lemma frequency (t(34)= 2.03, *p*= 0.065) and number of syllables (t(58)= 2, *p*= 0.063). Thus, even though, there is a trend toward a statistical significance of difference in the number of syllables, letters and lemma frequency between related and unrelated primes in the -er group of nouns, it does not reach significance.

500 fillers were added to 60 experimental items, such that half of the targets included existing words in German (280) and the other half (280) comprised nonwords constructed by changing one to three letters in the existing words. The word/word filler pairs included not only noun-noun pairs of different structure but also 210 verb-verb pairs. Of those 210 pairs, 36 were used as experimental items in the experiment by Neubauer and Clahsen (2009) but were not analyzed in the current experiment. Similarly to by Sonnenstuhl et al. (1999) we included 20 pairs in which the prime was contained in the nonword target (e.g., *Erbse* ‘pea’ – *Berbser*) and 20 pairs in which the prime and the non-word target partially overlapped (e.g., *Demokrat* ‘democrat’ – *Demolurst*).

The present study has not included control conditions, that is sets of items related only semantically or orthographically as it would have substantially increased the relatedness ratio which would have to be compensated for by including a large number of additional filler items. This measure would have substantially increased the duration of the experiment making it extremely long especially for older adults causing fatigue and loss of concentration. Absence of control conditions in the present experiment is a disadvantage. Note, though, that the results from the previously reported experiment in the chapter (see the section 3.1.7 Results) seem to indicate that in masked priming experiments “orthographic priming effects are typically nonsignificant or even inhibitory”

[18] Sonnenstuhl et al. (1999) note the difference between -s and -er plurals. Plural -er form show stem alternations (umlaut) as in *Blatt* ‘leaf’ – *Blätter* ‘leaves’, whereas – s plurals do not have any stem changes. This leads to the differences in the degree of orthographic similarity. This is a confound which we will address in the Chapter 3.2.7.

(Rastle, Lavric, Elchlepp, & Crepaldi, 2015, p. 15). If the potential differences between -er and -s plurals are found, they cannot be ascribed only to the semantic relatedness either, as the type of semantic relationship is identical in both cases anyway.

In total, the number of related items was below 23% (including related word/non-word pairs).

Four experimental lists based on a Latin square design were composed so that each target word was presented only once to a participant. To avoid possible fatigue effects the lists were presented in reversed order to half of the participants (see Appendix D for the list of all critical items).

Based on previous research on morphological processing and ageing several potential outcomes could be expected:

1) Similar priming effects for -er and -s forms due to the application of the blind affix stripping mechanism (Rastle et al., 2004) and preserved decomposition-based processing in both age groups (Duñabeitia et al., 2009; Kavé & Levy, 2004)

2) Stronger priming effects for -s forms than -er forms (Sonnenstuhl et al., 1999) reflecting the dichotomy between combinatorial and lexically stored items already at the level of access representations in both age groups (similarly to Neubauer and Clahsen (2009))

3) Less facilitation for -er forms with advancing age due to the decline of the declarative memory and weaker memory links (Clahsen & Reifegerste, 2017)

4) Alternatively, more facilitation for -er forms with advancing age due to the greater experience facilitating storage-based access (Reifegerste et al., 2017)

5) Higher accuracy and slower response latencies in older adults indicating a speed-accuracy trade-off as predicted by Ramscar et al. (2014)

3.2.6 Data analysis.

Data cleaning was first carried out based on the accuracy rates of participants and other factors such as whether participants reported being able to notice and read primes. Based on these criteria 2 experimental items were excluded from further analysis (-s plural set of nouns: *Brikett* ‘briquette’; *Embargo* ‘embargo’) due to the low accuracy (below 70%) in both groups of participants.

Further data cleaning involved the removal of all incorrect responses and timeouts (3.17% for the group of older adults and 3.62% for the group of younger adults). Next, cutoff points were applied to remove extreme values which were higher or lower than 2SD from the mean RT per participant. This has led to the removal of additional 3.7% of the remaining data for the older group, and 4.59% of the data for the control group of younger adults.

In order to normalize the distribution, the analyses were conducted based on the transformed RTs (inverse transformation). We analyzed RTs with mixed-effects linear regression models with crossed random effects for participants and items (see Baayen, Davidson, and Bates (2008)) using the languageR package (Baayen, 2008) and the lme4 package (Bates et al., 2014).

The model we fitted to the targets in the morphological set included Condition (Unrelated, Related, Identity) and Prime Type (Regular Plural / Irregular Plural) as a fixed effect. As predictors models included Trial Number (the position of the item in the presentation list; centered) to control for trial-level task effects, such as fatigue, Reaction Time on the Previous Item (inverse transformed, centered), Word Form frequency of the target (centered) and Lemma frequency (centered), Length (number of letters, centered).

Accuracy data were analyzed with generalized linear models with a binomial link function.

3.2.7 Results.

Table 21 illustrates mean accuracy rates, by-participant means, as well as standard deviations of RT data in each condition and in each set for groups of older and younger adults.

Table 21

Mean RTs, Standard Deviations and Mean Accuracy for -s and -er Plural Forms by Condition for Older and Younger Adults

	-s Plurals					
	Older adults			Younger adults		
	Identity	Related	Unrelated	Identity	Related	Unrelated
RT	667.45	706.12	748.68	583.13	620.15	655.28
SD	144.39	155.97	160.75	116.76	115.22	112.10
Accuracy (%)	94.42	89.37	84.44	92.46	87.28	84.93
	-er Plurals					
	Older adults			Younger adults		
	Identity	Related	Unrelated	Identity	Related	Unrelated

RT	611.47	628.82	661.12	551.80	586.95	598.31
SD	124.77	110.08	112.06	108.79	99.81	100.40
Accuracy (%)	94.45	96.55	96.89	93.24	96.22	96.22

Similarly to our analyses of previous experiments we will mostly focus on the data from older adults while treating a group of younger adults as a control group.

The accuracy analysis for the group of older adults in the set of irregular -er plural nouns failed to reveal any effect of Condition (all *p*s > 0.21). At the same time, older adults showed (marginally) more accurate responses after related than unrelated primes (β= -0.49, SD= 0.277, z-value= -1.779, *p*=.075) and significantly more correct responses after identity primes compared to related primes (β= 0.71, SD= 0.346, z-value= 2.08, *p*=.037) in the group of regular -s plurals. The analysis showed a significant main effect of Type indicating more accurate responses for -er plural nouns (β= 0.846, SD= 0.385, z-value= 2.194, *p*= .028) and interaction of Prime Type and Condition (related vs. identity) (β= -1.25, SD= 0.547, z-value= -2.285, *p*= .022) showing a greater difference in accuracy for -s nouns than for -er nouns following related compared to identity primes.

To examine response patterns of older adults in more detail we fitted a mixed-effect model to the latency data. See Table 22 for the model.

Table 22

The Best-fit Model for the RT data for the Older Participants

Random effects		Variance	SD
Item	Intercept	0.002593	0.05092
	Condition [unrel – rel]	0.0007614	0.02759
	Condition [ident – rel]	0.0022746	0.04769
Subject	Intercept	0.0294961	0.17174
	Condition [unrel – rel]	0.0011911	0.03451
	Condition [ident – rel]	0.0009169	0.03028
Residual		0.0370836	0.19257
Fixed effects	**Estimate**	**SE**	**t-value**
Intercept	-1.496	0.03578	-41.80

Length	0.03693	0.005309	6.96
Lemma frequency	-0.0001044	0.0002625	-0.40
Trial number	-0.0001289	0.00003294	-3.91
Word form frequency	-0.00005441	0.0004374	-0.12
Previous RT	0.0871	0.0201	4.33
Relevelled for -s plurals			
Condition [unrel – rel]	0.09047	0.01968	4.60
Condition [ident – rel]	-0.09299	0.02048	-4.54
Relevelled for -er plurals			
Condition [unrel – rel]	0.07938	0.01825	4.35
Condition [ident – rel]	-0.05945	0.01956	-3.04
Main Effect of Prime Type			
Prime Type [-s plurals – -er plurals]	0.1113	0.01869	5.95
Effect of Condition on Prime Type			
Prime Type – Condition [unrel – rel]	-0.01109	0.02532	-0.44
Prime Type – Condition [ident – rel]	0.03354	0.02716	1.23

The model shows that for the group of older adults a partial priming effect is observed for regular -s plurals as participants react significantly faster to targets following related items than unrelated items (t= 4.6) and at the same time significantly slower than after identity primes (t= -4.54). The same pattern is also observed for irregular -er nouns with faster response latencies following related than unrelated primes (t= 4.35) and slower responses following related compared to identity primes (t= -3.04). The lack of significant interaction effects between -er and -s plural forms indicates parallel response patterns in presence of the main effect of Prime Type (t= 5.95). Furthermore, several predictors turned out to be significant and namely the trial number (t= -3.91), the RT to the previous item (t= 4.33) and the length of the target (t= 6.96). In accordance with Baayen et al. (2011) the positive slope for the previous target RT could be taken as an indication of the consistency in the participants' behavior across the trials, while the negative effect of trial shows the increase in experience as participants progressed through the experiment. Similarly, the positive slope for word length was expected and indicates the slower response latencies of the participants with the increase of the length of the target.

3.2.7.1 Between-group comparisons.

To investigate whether accuracy patterns found in the group of older adults differed from patterns found in the control group of younger adults the best-fit generalized linear model included the interaction between Age Group and Prime Type to a minimally different model without such an interaction. This comparison revealed that interaction does not significantly improve model fit ($\chi 2(2) = 0.32$, p = .852). The omnibus analysis of the error data found no main effect of Age Group (β = -0.15, *SE* = 0.147, *z* = -1.02, *p* = .305), with older and younger speakers showing overall similar accuracy rates as well as no simple effect of Age in the unrelated condition (β = -0.04, *SE* = 0.252 *z* = -0.161, *p* = .872).

To investigate the possible difference between two age groups with regard to RT data we compared an omnibus model including an interaction between Prime Type and Condition and Age group and a minimally different model with the interaction term removed and three two-way interactions. Model comparisons using the anova() function showed, however, that including the critical interaction did not significantly improve the fit of the model [$\chi 2(2) = 2.453$, p = .29] compared to the model with three two-way interactions between Type and Condition, Type and Age, Condition and Age.

Even though priming effects appear to be similar for the two groups, we fitted an additional model to the data of the control group of younger adults to separately investigate priming effects (see Table 23).

Table 23

The Best-fit Model for the RT Data for the Group of Younger Adults

Random effects		Variance	SD
Groups	Intercept	0.0081494	0.09027
Item	Condition [unrel – rel]	0.0024939	0.04994
	Condition [ident – rel]	0.0041326	0.06429
	Intercept	0.014745	0.12143
Subject	Condition [unrel – rel]	0.0003699	0.01923
	Condition [ident – rel]	0.0014373	0.03791
		0.04514	-0.04

Random effects		Variance	SD
Residual		0.0449325	0.21197
Fixed effects	Estimate	SE	t-value
Intercept	-1.676	0.0295	-56.81
Length	0.03703	0.007216	5.13
Lemma frequency	-0.000449	0.0003543	-1.27
Trial number	-0.0002542	0.00003213	-7.91
Word form frequency	0.0004597	0.0005927	0.78
Previous RT	0.1608	0.0193	8.33
Relevelled for -s plurals			
Condition [unrel – rel]	0.09868	0.02011	4.91
Condition [ident – rel]	-0.1274	0.02190	-5.82
Relevelled for -er plurals			
Condition [unrel – rel]	0.03036	0.01863	1.63
Condition [ident – rel]	-0.1188	0.02088	-5.69
Main Effect of Prime Type			
Prime Type [-s plurals – -er plurals]	0.0696	0.02759	2.52
Effect of Condition on Prime Type			
Prime Type – Condition [unrel – rel]	-0.06832	0.02704	-2.53
Prime Type – Condition [ident – rel]	0.008564	0.02895	0.30

For the set of -s plurals, the results in the group of younger adults indicate a partial priming effect because participants react significantly faster to targets following related items than unrelated items (t= 4.91) while being slower after related than after identity primes (t= -5.82). However, the results for -er plural nouns look differently and while there is a trend toward the partial priming effect, it does not reach significance because response latencies following related primes are not significantly faster than following unrelated primes (t= 1.63) while being slower than after identity primes (t=-5.82). This difference is further confirmed in the direct comparison of Prime Type and Condition (related vs. unrelated) which reaches significance (t=-2.53) showing differences between the two sets.

Since there was a statistically significant difference between priming for -er and -s plurals in the group of younger adults and numerical difference in the group of older adults, we have examined an interaction of Prime Type (-er vs. -s) and Condition (identity vs. related; unrelated vs. related) in the omnibus model while averaging across two age groups using a deviation contrast. The model indicated that while the interaction of Type and Condition (identity vs. related) was not significant (β= -0.024, SE= 0.024, t= 1.00), the interaction of Type and Condition (unrelated vs. related) was significant (β= -0.042, SE= 0.019, t= -2.21). The latter interaction shows larger priming for -s plurals in German (averaged across two age groups). As our separate analysis of the data for younger speakers of German indicates, this overall difference is mostly carried by the group of younger adults as older adults show robust priming effects for both -s and -er plurals.

We also investigated whether the priming effect in general is larger or smaller for older adults while averaging across Type (-er vs. -s). This analysis has shown that interaction of Age (old vs. young) and Condition (identity vs. related) is significant (β= 0.043, SE= 0.018, t= 2.33), indicating that on average younger people react significantly slower than older people after related compared to identity primes. This shows a stronger repetition priming effect elicited by the group of older adults.

Crucially, the model also showed a general effect of slowing as shown by the significant main effect of Age as well a simple effect in the unrelated condition (β= 0.15, SE= 0.037, t= 4.02 and β= 0.14, SE= 0.035, t= 4.19, respectively).

Intriguingly, the difference between -er nouns and -s nouns found in the present experiment for younger adults (i.e., the difference between a partial priming effect and the absence thereof) and overall larger priming for -s plurals is similar to the differences observed in the experiment by Sonnenstuhl et al. (1999), who reported a full priming effect for -s plurals and partial priming for -er plurals in the cross-modal priming experiment.

The observed difference in priming patterns for -er plurals between older and younger adults should be interpreted with caution. This difference may not be entirely reliable because even though the priming patterns differ, the lack of significant three-way interaction between Age, Condition and Type and the fact that inclusion of this interaction does not result in a model with a better fit calls this interpretation into doubt. While the difference between older and younger adults might not be completely reliable in the present study, the differences between -er and -s plurals within younger adults should be investigated further.

As Sonnenstuhl et al. (1999) noted, the observed difference between -s plurals and -er plurals might have alternative explanations, for instance, it might be due to the fact that around 25% of the -er plurals included in the experiment are in fact derived items in contrast to morphologically simple -s plurals. In order to address this potential confound we removed derived nouns from the set of -er nouns and examined the set of underived -er nouns only. For the remaining set we also found no priming effect (i.e., no difference between related and unrelated conditions) (Related vs. Unrelated: β= 0.026, SE= 0.029, t= 1.35).

Another explanation of the observed differences between -er and -s plurals refers to the degree of the formal overlap, as multiple -er plural nouns involve stem changes such as *Buch* 'book' – *Bücher* 'books' whereas none of the -s plurals undergoes any stem changes. To address this issue we have included the degree of the orthographic overlap (using a spatial coding scheme) between related primes and targets, calculated using the Match Calculator by Colin Davis (http://www.pc.rhul.ac.uk/staff/c.davis/Utilities/MatchCalc/), as a continuous variable. Then we compared a model which included the interaction of Condition, Prime Type and the degree of Orthographic overlap (centered) to a model with no interactions as well as to a model presented earlier which does not include the degree of Orthographic overlap as a predictor at all. In neither case, the interaction produced a better model ([$\chi2(5) = 5.16$, p = .396] and [$\chi2(6) = 7.736$, p = .258], respectively).

Thus, the degree of the overlap cannot account for differences in priming effects between -er and -s plurals established by comparing response latencies in related and unrelated conditions. To even further investigate the role of the factor we divided 30 -er plural nouns into two groups of 23 and 7 items depending on whether the plural form had an alternated stem or not. In both groups the difference between related and unrelated conditions was not significant (β= 0.027, SE= 0.019, t= 1.40 and β= 0.022, SE= 0.038, t= 0.60, respectively).

Considering the overall analysis assessing the role of the orthographic similarity, it appears that the larger overlap between related -s primes and targets compared to related -er primes and targets cannot account for the differences in priming patterns observed in the group of younger adults. Thus, the difference in results between -er and -s plurals appears to be primarily due to the distinction between two affixes themselves.

Furthermore, although this experiment did not have an independent orthographic control set, the fact that the degree of the orthographic similarity does not produce better models also indicates that the observed priming effects are not simply due to the surface form overlap.

Moreover, even though the results for the control group of younger adults may remain somewhat controversial, the data for the experimental group of older adults showing equal facilitation for both -er and -s plurals are hard to account for based on the role of the orthographic overlap alone.

The findings from the earlier reported experiment in the Chapter 3.1.7 indicating absence of any priming effects in the orthographic set could be also considered as being relevant for the present experiment. Note that this comparison is possible given absolutely identical experimental procedures including the equal duration of the visually presented primes in both experiments (50ms). Note, however, that the orthographic control set in the experiment on processing of inflected and derived words included two types of pairs, that is with the word-initial and word-final overlap. To mimic the type of the overlap in the present experiment, we have additionally examined only the word-initial orthographic pairs (12 pairs in total). The analysis indicated no facilitation for word-initial orthographically overlapping items (identity vs. related: β= -0.145, SE= 0.029, t= -4.85; unrelated vs. related: β = 0.03, SE= 0.032, t= 0.94). This is additional although somewhat indirect evidence, that any observed differences in the group of younger speakers of German are not attributable to the orthographic overlap but are due to the nature of the inflectional endings.

3.2.8 Discussion.

The experiment reported above examined the processing of -s and -er plural forms in German. Importantly, findings from several previous experimental studies have suggested a possible dichotomy between -s and -er forms. It has been assumed that -s affixation might be rule-based in German as it is productive and can be generalized to novel words whereas -er is considered to be irregular and unproductive. Thus, complex words involving -s or -er affixation could be processed differently according to the claims of the dual-route model which assumes decomposition of -s plurals into corresponding constituents and whole-word access of -er forms.

Note though, that the differences were usually found in experiments tapping into central representations and should not necessarily be observed in a masked priming experiment which may involve a blind decomposition into morphological constituents which is often referred to as an affix stripping mechanism. If one considers this assumption, then similar priming effects for *Kind+er* and *Auto+s* might be expected. However, there are several reasons to raise doubts regarding blindness and robustness of the supposed mechanism. On the one-hand, experiments reporting facilitation effects for *fell-fall* cases which cannot undergo any decomposition indicate existence of other access mechanisms for irregular forms that are used at the level of access representations. Furthermore, even for forms which in principle could be decomposed such as irregular participles in German (e.g., *ge-schlaf-en* ‘slept’), priming effects were indeed reported but, crucially, they were reduced relative to those found for regular verbs (e.g., *ge-mach-t* ‘done’) as reported, for example, by Neubauer and Clahsen (2009) which were interpreted in accordance with the dual-route model. Thus, experimental evidence does not exclude the possibility of observing differences between presumably rule-based and lexically-stored forms during processing at the level of access representations.

On the other hand, there are also theoretical reasons to suspect, that the robustness of the reportedly blind affix stripping mechanism depends on the properties of the language and its spelling system, which either more consistently distinguishes affixes from homophonous final letter sequences of the monomorphemic words as in English or French, or less as in German (Aronoff et al., 2016). Furthermore, it is unclear how reliable in the general the evidence in favor of the blind morphological decomposition is as some studies including, for instance, by Rastle et al. (2004) could be criticized for the choice of the experimental stimuli. Baayen et al. (2011) examined the materials by Rastle et al. (2004) and noticed that among pseudo-derived words, such as *corner,* it also included the words such as *fruitless* which could be used in its literal meaning in English (*fruitless tree*) etc. In other words, the affixes still conveyed the regular meanings (as in *archer* or *early*). Thus, it may well be the case, that the difference between -er and -s plural affixes in German could be revealed even in a masked priming experiment.

The current experiment evaluated the claims made above and examined whether a masked priming paradigm would allow us to observe a difference between rule-based -s plural forms and irregular -er forms or whether similar priming effects would be observed for both forms in conformity with the robust mechanism of the early affix segmentation. In addition, we focused on testing whether there are any effects of ageing on processing of the morphologically complex forms.

The results obtained from the group of older adults have shown facilitation effects for both -er and -s plural nouns in German. The magnitude of facilitation was found to be statistically similar for both types of plural forms as well. In order to assess the role of ageing we have conducted an overall analysis comparing the model which included the interaction between Prime Type, Condition and Age Group to the model without a threeway interaction. The model comparison has shown that the interaction between Prime Type, Condition and Age Group is not significant indicating similarities across two age groups with regard to the priming effects. The omnibus model has also revealed the differences between priming effects for -er and -s plural forms (averaged across two Age groups) with a larger magnitude of priming for -s than -er plurals. To examine the source of this difference we examined priming effects for younger adults and established that this overall difference appears to be mostly carried by the group of younger adults as only identity priming reaches statistical significance whereas the 12ms difference between related and unrelated conditions for -er plurals does not.

One could hypothesize why less facilitation was observed for -er plural, especially in the group of younger adults. Note that as mentioned earlier, even though masked priming experiments are usually assumed to yield automatic decomposition as shown by *corner – corn* effects, there are some indications that differences between regular and irregular forms could be also observed not only, for example, in cross-modal priming studies but masked priming studies as well. For instance, Neubauer and Clahsen (2009) reported a full priming effect for regular participles and a partial priming effect for irregular participles in German. Both of these could be theoretically decomposed into their constituent morphemes (and should be decomposed according to the claims, for example, by Smolka et al. (2013)). Although Neubauer and Clahsen (2009) do not discuss their results in light of the presumed automatic decomposition of all morphologically complex or even pseudo-complex forms, one might consider the assumptions made by Aronoff et al. (2016) who assumed that automaticity and blindness of the early decomposition-based processing may vary cross-linguistically and may be affected by the properties of the spelling system and, crucially, the salience of affixes.

They assume that English and French differ from German, as both English and French distinguish affixes more consistently from homophonous final letter sequences of the monomorphemic words than German. With regard to -er, Aronoff et al. (2016) note that there are very few morphologically simplex words such as *corner* in English ending in -er, whereas in German it is not the case. Thus, while chopping off final -er in English would almost always yield a correct analysis, this approach may be less reliable in German due to its higher error rate. Consider also similar claims made by Köpcke (1988) who attributed poorer cue validity to -er as a plural marker in German than to -s affix. Note, that the account by Aronoff et al. (2016) is not specific to -er affix but is more general and invokes cross-linguistic differences.

Consider the existence of further differences in properties between -s and -er plural affixes. For instance, according to Wiese (2000), irregular affixes are assumed to resemble some derivational affixes classified as Class I affixes which are considered to be 'root-close' affixes. This fact is among others reflected in their morphological properties, such as the possibility to precede derivational affixes as in *Kind-er-chen* or *Völk-er-schaft* where -s cannot occur. The findings reported by Neubauer and Clahsen (2009) also appear to be compatible with the claims that the decomposition mechanism in German does not act indiscriminately but rather takes into account the linguistic differences existing between various inflected forms. The differences were indeed postulated by Marcus et al. (1995) and Clahsen (1999a) who considered the -s affix to be a default plural marker in German and, hence, -s plurals to be rule-based while other plural forms including -er nouns are lexically stored. In terms of the account by Wiese (2000) the differences between examined plural affixes in German could also be seen as the opposition between level 3 and level 1 affixes. Level 3 affixes and truly rule based in a sense that no lexical listings are required, while irregular level 1 affixes essentially require lexical listings because even though it is also possible to represent them descriptively as rule-based, the rules have to be extremely specific and apply to only specified set of nouns.

If the claims regarding linguistic differences between -er and -s plural forms are correct, then the dichotomy between -er and -s plurals observed in our masked priming experiment becomes explicable and could, similarly to the findings reported by Neubauer and Clahsen (2009) reflect the morphological differences between regular and irregular forms in line with the dual-route model which would assume decomposition of the regular -s forms and lexical storage of -er forms (Clahsen, 1999a; Marcus et al., 1995; Sonnenstuhl & Huth, 2002). This difference cannot be attributed to the type frequency of both affixes in German or as indicated by the statistical analyses to the degree of the orthographic overlap. The fact that we found differences between -er and -s plural forms despite a similar type frequency would contradict the assumptions of the usage-based models, for example, by Bybee (1995) and Köpcke (1988). It should be stressed, however, that the contrast we observed is mainly carried by the group of younger speakers and is not significant in the group of older adults.

Overall, the results of this experiment show a stronger facilitation for -s plurals than for irregular -er plurals especially in the group of younger adults with this effect being attenuated with ageing. If the observed difference between -er and -s plurals in the group of younger adults is indeed due to the distinct processing mechanisms reflecting linguistic properties of -er and -s forms, then processing of -er plurals is similar to the famous *fell-fall* priming effect reported by Crepaldi et al. (2010) and is lexically-mediated in contrast to the decomposition-based processing of -s plural forms. These mechanisms are schematically represented in the Figure 6 below: indicating decomposition of the -s plural forms into a stem *Auto* and an affix *-s*, whereas priming for the -er plural form *Kinder* is not due to its decomposition into a stem *Kind* and an affix *-er* and subsequent direct reactivation of the base *Kind,* but rather because it is a subentry to the main entry *Kind*.

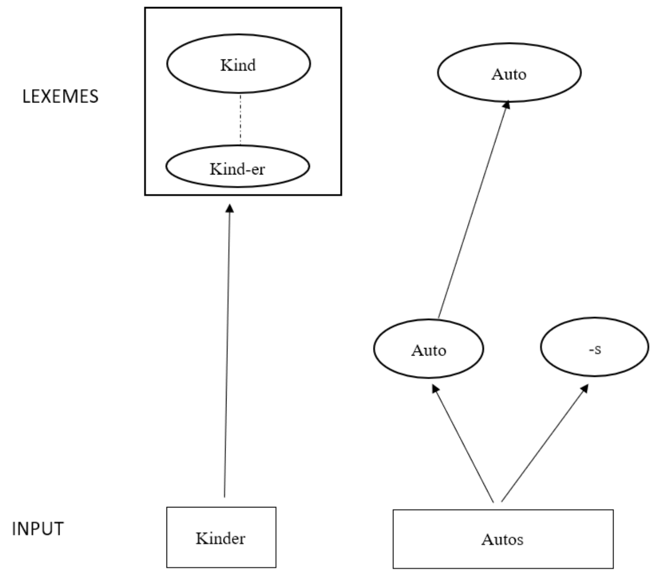

Figure 6. Word-form representations for irregular plural inflected forms (-er forms) and regular plural forms (-s forms)

Note that the processing advantage of the -s plurals over the -er plurals effect is numerically present in the group of older adults as well. One explanation for the increase of facilitation for -er plurals in older speakers might be due to their lifelong experience and the therefore stronger links between various forms in the mental lexicon. Interestingly, this interpretation is in line with the one proposed by Reifegerste et al. (2017) who suggested that the lifelong experience could boost whole-word access in processing of plural forms in German though it was assumed that younger adults decompose all plural forms. Note, however, that they used a different method, that is the unmasked lexical decision method, to investigate processing of such forms complicating the direct comparisons of the findings.

With regard to the processing of regular -s plural forms, the results of the present study concur with the previous findings, for instance, with the data from the experiment on processing of regular- t participles in German. Similarly to data from Hebrew by Kavé and Levy (2004) and Spanish by Duñabeitia et al. (2009), our data also demonstrates that the decomposition-based mechanism of processing appears to be intact in older adults, at least, as indicated by behavioural data from cross-modal and masked priming experiments.

This experiment also finds evidence of the general slowing of older adults and also demonstrates that the general slowing and higher accuracy do not necessarily go hand in hand and, hence, run against the predictions of the simulation models by Ramscar et al. (2014). If one had also observed higher accuracy rates, slower response latencies could have been interpreted not as an effect of decline but rather of lifelong learning. In the present experiment no evidence was found in favor of "a picture in which an improvement in one dimension – accuracy – is shown to come at a cost in another, speed" (Ramscar et al., 2013, p. 36). Instead, the results of the present study show only generally slower response latencies of older adults.

Overall, one can conclude that the present findings found no convincing evidence that early morphological processing is selectively affected by ageing as we found largely similar priming effects for older and younger adults during processing of plural forms in German and no interactions between the two age groups. Interestingly, there are some signs of processing differences between -er and -s plurals at the level of access representations carried mainly by younger adults which disappear in the group of older adults. This finding may reflect the effects of experience rendering storage-based lexical access more robust. The reliability of this effect should be given more attention in the future studies.

4 General Discussion and Conclusions

In this chapter I will briefly review some crucial findings from experiments conducted in Russian and German which investigated morphological processing in older adults. Then I will provide a possible interpretation of the major results.

In the first experiment we investigated the processing of words derived by means of the -ost' affix in Russian such as *glupost'* 'stupidity' from *glupyj* 'stupid'. The process of nominalization is fully productive and predictable and involves the application of the -ost' affix to the adjectives. Considering previous findings from other studies conducted on Russian which also used the masked priming method to investigate access mechanisms and the structure of the mental representations of such words, we hypothesized that derived words might be stored in the mental lexicon but their representations are morphologically structured.

If this is indeed the case, we expected a robust priming effect showing the combinatorial processing of such complex words, that is decomposition into the stem + affix -ost'. This assumption was further backed up by several studies indicating that the masked priming technique may tap into the initial and automatic stage of word processing characterized by application of the "blind affix stripping mechanism". The results of our experiment show a robust priming effect in the group of older adults in line with the claims that derived words are segmented into their constituents.

In the second experiment on Russian we examined the processing of 1P. Sg present tense inflected forms. The experiment included two types of stems: stems of -aj verbs which undergo no allomorphic stem changes such as *igraju* 'I play' – *igrat'* 'to play' and verbs with stem alternations. It should be noted that the latter group included two subtypes of verbs, that is -i verbs with allomorphic changes which are usually described as predictable, for example, *košu* 'I mow' – *kosit'* 'to mow' and verbs from various minor classes with idiosyncratic changes, for example, *moju* 'I wash' – *myt'* 'to wash'. Importantly, the inflectional endings themselves are identical for all verbs. The experiment sought to test whether internal properties of the stem, such as presence of allomorphic changes and their nature (predictable / idiosyncratic), lead to processing differences which may reflect a contrast between two types of representations, that is compositional for -aj stems (root + inflectional class marker -aj) and non-compositional for other stems with allomorphic changes at least at the initial stage of word comprehension.

In our experiment the results obtained from the older adults indicate significant priming effects (and absence of difference between identity and related conditions) for -aj verbs without stem changes and also facilitation for verbs with stem changes. In the latter group, however, we observed significantly slower response latencies in the related condition compared to the identity condition. This difference could be restated in terms of a full priming effect observed for verbs without stem changes and a partial priming effect for verbs with stem changes. Furthermore, we also found a significant interaction between two groups indicating a larger magnitude of facilitation for -aj stems than for allomorphic stems following related primes compared to unrelated primes. Within the group of stems with allomorphic changes we observed similar patterns and similar magnitudes of priming for stems with idiosyncratic changes and stems with predictable allomorphic changes (i.e., -i stems which show alternations in 1P.Sg., forms of the stem final dental, velar and labial consonants, such as *d → ž*, *t → č* or *b → bl'*). In our view the similarity between two groups of verbs with stem changes might imply a single processing mechanism and similar representations regardless of the nature of allomorphic alternations.

The observed results could be thus interpreted as indicating a contrast between non-compositional forms such as *košu* 'I mow' and compositional forms such as *igraju* 'I play'. This difference could be schematically as in the earlier presented Figure 5:

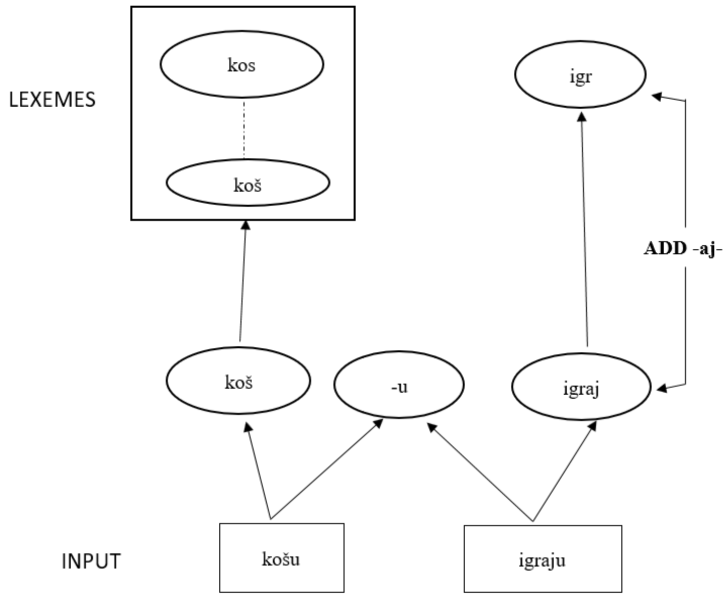

Figure 5. Word-form representations for inflected words with stem changes (e.g., -i verbs) and without stem changes (e.g., -aj verbs)

The very first step in recognition of both complex forms is identical and involves stripping off the inflectional affix -u. The following step, however, differs for two stems. As further decomposition of the allomorphic stem *koš* is impossible, its recognition is based on the same mechanism which was proposed for forms such as *fell – fall* in English by Crepaldi et al. (2010). The allomorphic stem *koš* in Russian constitutes a subentry of the main stem *kos.* Thus, *koš* activates *kos* through a shared lexeme entry, which then facilitates the recognition of the corresponding target word with *kos* stem bringing about the observed priming effect. For stems without allomorphic changes such as *igraj* further processing involves full decomposition of the stem down to the root *igr-* after stripping a verbal classifier -aj which is involved in formation of -aj conjugation stems. The root then directly facilitates recognition of the corresponding target with the same root *igr-* leading to a robust facilitation effect.

Our claim is also compatible with the assumption made by Kazanina et al. (2008) who argue that morphological decomposition in Russian is exhaustive based on the masked priming study with pseudo-derived words such as *lunk-a* 'hole-Nom.Sg' processing of which apparently involves stripping of the word internal *-k'*. On the whole, our assumption concerning the processing of -aj stems is in line with the claim that -aj stems are the least marked one if one uses the terminology of the markedness-based theories (Feinberg, 1996) and that -aj verb stems are fully compositional and represent a combination of a root and a stem-formation verbal classifier.

Our results provide evidence indicating similar processing mechanisms and access representations for all stems with allomorphic changes with apparently no distinction between stems with idiosyncratic changes and alternations which could be perceived as rule-based as in case of *š/s* changes in -i stems. In our view, these findings do not support the rule-based account of stem-alternations as proposed by Estivalet and Meunier (2016) for verbal inflection in French, who have not, however, examined verbs with truly idiosyncratic changes in French. In this case one might expect differences between allegedly rule-based alternations of -i stems, resembling rule-based formation of -aj stems, and clearly idiosyncratic changes of other stems with more facilitation in case of rule-based alternations.

Similarly, the claim made by Stockall and Marantz (2006) predicting across-board decomposition for forms with complex allomorphy in English "even when that process of parsing does not involve simply stripping off linearly adjacent affixes" (Morris & Stockall, 2012, p. 92) could not fully explain the observed patterns of results. On the one hand, this approach would require complex rules which may apply in some cases to a set of only one or two items. On the other hand, it also fails to account for the observed difference between stems with and without alternations and absence of such differences between two types of stems with allomorphic changes. If the processing mechanism is identical and involves decomposition in all three groups, then observed differences in facilitation effects could be in principle due to the degree of orthographic consistency between primes and targets.

However, two groups of verbs with stem changes show similar effects despite larger consistency in the group of -i stems. Under our view, the observed pattern better fits with accounts which distinguish between decomposable and non-decomposable and, hence lexically-stored complex forms. Such a proposal can easier explain similarities between two subgroups of verb forms with stem changes as such stems are considered to be lexically stored.

It remains to be further investigated why fully predictable alternations typical of -i class pattern with idiosyncratic alternations (at least during initial stages of word processing) as this finding appears to be unexpected. Even though this pattern still awaits its explanation one might, perhaps, assume that while it may be descriptively useful to refer to alternations as rule-based in linguistic literature, this approach might not necessarily reflect the psycholinguistic evidence. Chernigovskaya and Gor (2000) have found that in the elicited production task nonce verbs derived from existing -i verbs were conjugated as -i verbs in only about one third of all responses. Since it was required to produce forms in 1P.Sg. (as well as 3P.Pl.), which for the included verbs (such as *trosit'* from *prosit'* 'to ask') would imply stem alternations, one could conclude that in two thirds of all responses participants avoided applicatication of stem alternations.

Similarly, Slioussar and Kholodilova (2013) have examined relative frequencies of forms with and without alternations generated from existing novel and substandard verbs in Russian (e.g., *apgrejdit'* 'to upgrade') based on search results in the internet. On average, such verbs lacked alternations in 27.6% of cases. However, the incidence of forms without alternations was much higher for certain categories of verbs. For instance, for frequent[19] verbs ending in obstruent clusters it was about 62.3% (for infrequent 68%) and for frequent verbs ending in non-labial consonants it was 41.8% (for infrequent 67.2%). Taken together, these data could indicate that speakers of Russian may not treat alternations as based on productive abstract rules (stem-final consonant X becomes Y in 1st P.Sg.) and appear to often ignore them (Slioussar & Kholodilova, 2013). Instead, the application of stem alternations to only some novel verbs may indicate its analogy-driven nature similarly to irregular forms in English or German. In this case our results showing similar patterns for -i verbs and verbs with idiosyncratic stem alternations appear less surprising and are in line with studies raising doubts about the rule-based nature of -i stem alternations from the psycholinguistic point of view.

The robust contrast between forms with and without stem changes in older adults also does not support the claims of single-mechanism accounts of word recognition such as the supralexical or "whole word perspective" approach by Giraudo and Dal Maso (2016). According to this approach whole-word representations are always accessed first during the word recognition process. The supralexical approach considers morphological units to act not as just access units corresponding to certain elements of words such as stems and affixes but to be more abstract in nature. Accordingly, the processing of morphemes is less influenced by their surface realization and allomorphy. If it were indeed the case, one would predict similar patterns of results for all groups of verbs as word comprehension is posited to involve activation of whole words. Moreover, subsequent activation of constituent morphemes should not presumably lead to any processing differences either as surface realization of morphemes does not play a significant role in the supralexical model. These claims appear to run against the observed findings and, hence, allow us to conclude similarly to Estivalet

[19] As frequent the authors treated verbs with at least 100 1P.Sg. forms found on the internet

and Meunier (2016, p. 11) that at least verbs without stem changes "undergo full decomposition that occurs pre-lexically and is used for lexical access and word recognition".

Other single-mechanism approaches including a family of associative models, which treat morphological structure as an emergent property arising due to shared semantic and phonological connections, appear to have troubles explaining observed findings as well. First and foremost, our experiments examining the processing of derived and inflected complex forms in Russian show that facilitation observed for morphologically related words could be distinguished from facilitation for semantically and orthographically related words. While it is true, that for some morphologically related words such as verbs with stem changes semantic or orthographic relatedness could account for facilitation effects, this explanation becomes more problematic in case of derived words and verb forms without stem changes. In both cases, observed facilitation effects are substantially larger than those observed in the control sets in each experiment. Moreover, numerically they even exceed combined facilitation effects of semantically and orthographically related words (44.3ms vs. 17.4ms for derived words, 41.3ms vs. 26.5ms for verbs without stem alternations).

Taking into account the patterns discussed above, non-morphological factors could hardly explain the facilitation effects observed for derived words and verbs without allomorphic changes. Note that the degree of orthographic similarity alone could not explain a sharp reduction in priming for verbs with allomorphic changes since one would then expect to observe a gradual difference between two groups of verbs with stem changes expecting more facilitation for a group with larger orthographic overlap and specifically for -i verbs. This was not the case in our experiment. Thus, reduced facilitation effects for verbs with stem changes appears to point to a difference between morphological processing mechanisms rather than to reflect simple surface form properties especially considering clearly larger priming for forms without any stem changes than for matched orthographically related items.

While alternative proposals would have difficulties explaining observed priming patterns, an account presuming fundamental differences between combinatorial and lexically stored forms better fits for the obtained data. However, this hypothesized contrast between two processing mechanisms and representations could be limited to the initial processing stage when a parser has only partial access to the information about a presented word form in contrast to the full access available under certain conditions, for example, in cross-modal priming. Several cross-modal priming experiments, for example, by Gor and Jackson (2013) on Russian verbs and Reid and Marslen-Wilson (2002) on Polish verbal forms with similar properties failed to observe any differences between verbs without stem changes and verbs with two types of allomorphic changes (verbs with predictable and idiosyncratic alternations). Therefore, it has been assumed that a uniform set of mechanisms is applied to all types of verbs. These conclusions remain, however, controversial due to several reasons including lack of control sets as well as absence of an identity condition which could have produced differences between various types of verbs as it is indeed the case in the present study. Therefore, the role of stem alternations at more advanced stages of processing still remains not fully clarified.

It has been already observed, for instance, by Kırkıcı and Clahsen (2013) that under certain circumstances, for instance, in challenged populations such as language learners processing of inflected and derived words might yield dissimilar patterns of priming. Whereas inflection produces only word forms, derivation produces new lexemes (Anderson, 1992). Therefore, whereas a facilitation effect is posited to arise only due to decomposition of the word into stem + affix in case of inflected forms, it could be also lexically mediated in case of the derived words as the corresponding lexeme such as *[bitter]-ness]*$_N$ is partially shared with the lexeme of the base word *[bitter]*$_{Adj}$ leading to a priming via the lexical processing route (Kırkıcı & Clahsen, 2013). The assumption of the latter route gained experimental support due to the observed robust priming effects for derived words and absence of facilitation for inflected words. This, however, is only the case in the rather special group of participants and specifically language learners (Kırkıcı & Clahsen, 2013). This finding was taken to support the linguistic distinction between processes of derivation and inflection which is otherwise hard to detect in more typical populations.

Taking the observation above as a starting point, we have directly compared facilitation effects for derived and inflected words in Russian in another special group of speakers such as older adults. Though we have originally conducted two separate experiments testing the processing of derived and inflected words the same participants took part in both experiments and it was done in one session. This comparison was justified considering that the experimental design was identical in both cases.

The comparison between derived -ost' nouns and verbs without stem changes has shown a similar amount of facilitation. Moreover, the similarity is even more convincing if one takes into account the observed pattern of priming. Both derived nouns and verbs without stem changes elicit a full priming effect in contrast to verbs with stem changes and both differ from purely semantic or orthographic control sets. As discussed earlier, the priming effects for inflected forms, for instance, of -aj verbs is due to decomposition of the complex primes down to the root. With regard to the derived words the same morphological decomposition-based mechanism and subsequent stem reactivation could account for the priming effects. As Kırkıcı and Clahsen (2013) assumed, derivational priming could in principle make use of structured lexical representations of derived words such as *[glup]$_{Adj}$-ost']$_N$* 'stupidity' which allow for the access of the base stems, for instance *[glup-]*. Experiments on native speakers apparently do not allow to determine with certainty which route is employed, though it appears that the latter one is mainly invoked in order to account for patterns of non-native processing (see, for instance, Jacob et al. (2017) as well as Kirkici amd Clahsen (2013)). In sum, we conclude that the present study on Russian is in line with other studies which tend to find similar patterns for derived and inflected words in native speakers.

To further investigate processing of derived and inflected words we have conducted an experiment on comparable phenomena in German. We have tested the processing of nouns derived by means of the -ung affix in German such as *Gründung* 'foundation' – *gründen* 'to found'. This word formation process could be seen as being similar to -ost' derivation in Russian as it is equally productive and used to derive new nouns with abstract meanings. To study the processing of inflected forms in German regular -t past participle forms such as *ge-gründe-t* 'founded' were selected. This process could be compared to Russian -aj verbs without stem changes. Formation of regular -t participles in German does not involve any stem changes and is fully productive as well. By and large properties of -ung derivation and -t participle formation appear to be highly similar. The crucial difference between -ung and -t forms lies in the nature of linguistic processes, that is derivation and inflection. Whereas derivation is used to produce new lexemes, inflection is involved in production of new word forms. As mentioned earlier, it has been hypothesized that if one focuses only on masked priming studies this difference between two processes may be observed under rather specific circumstances such as in challenged populations including non-native speakers.

Indeed, Jacob et al. (2017) have examined processing of derived -ung nouns and -t participles in language learners and have found no priming for inflected forms whereas priming for derived words was preserved. Until now, it remains unclear whether one could find evidence in favor of a distinct processing mechanism in other challenged populations including older native speakers. We used the experiment developed by Jacob et al. (2017) to address this question.

The experiment testing the processing of derived -ung forms and inflected -t participles in German by older adults have shown facilitation effects for both morphologically complex forms. Moreover, the magnitude of priming for derived and inflected words was similar. Notably, the observed facilitation effects are unlikely to be due to the semantic and/or orthographic relatedness between primes and targets because in our experiment on German we found no priming in the control sets. Therefore, the accounts which rely on non-morphological factors as potential causes of facilitation effects are not supported by observed priming patterns.

Similarly to earlier discussed data on the processing of derived and inflected forms in Russian our results on German also do not produce a clear contrast between two types of word formation processes, that is derivation and inflection. Apparently, the effects observed by Jacob et al. (2017) as well as Kırkıcı and Clahsen (2013) can not be automatically applied to other challenged groups of speakers such as older adults and remain, perhaps, restricted to non-native language processing. Our results on German are in line with other masked priming studies which found similar effects for derived and inflected words in typical populations such as younger adults and resemble our own findings on Russian. Therefore, following Kırkıcı and Clahsen (2013) we would assume the same processing mechanisms for derived and inflected words as posited earlier for Russian.

Our second experiment on German similarly to the previously reported experiment on Russian focused on inflected forms. This time, however, we investigated the processing of plural noun forms in German such as *Autos* ‘cars’ – *Auto* ‘car’ or *Kinder* ‘children’ – *Kind* ‘child’. The difference between these forms could be stated according to Marcus et al. (1995) in terms of the contrast between regular and irregular forms. This contrast cannot be readily examined in Russian where all tested verbal forms bear an inflectional marker -u. In German, however, plurality can be expressed in a number of ways and it has been hypothesized that -s plural affix is a default one and, hence, -s plurals are fully combinatorial forms in nature in contrast to other forms[20].

In general, plurality in German can be signaled on nouns in five following ways, that is by -s, -(e)n, -er, -e and ∅. Among all possible markers of plurality, -s and -(e)r have been often treated as being completely distinct with regard to principal linguistic properties. Despite relatively low type frequency of both affixes in German of about 2% – 4% they differ in many other respects. Application of -s appears to be far less restricted by gender, syllabic structure and other morphophonological properties of nouns than application of all others plural markers. In essence, it appears to function as an “emergency” affix which could explain its productivity. In contrast, -er can be found only in the restricted set of items and is not used productively in modern German. Thus, it has been suggested that -s and -er plural forms provide a contrast between combinatorial and

[20] It has been also argued that class-specific predictable $-en_{fem}$ forms may be combinatorial as well at least at the level of modality-independent central level representations (Sonnenstuhl & Huth, 2002)

lexically-stored forms. Moreover, -er forms could be stored as frozen forms and have no internal morphological structure much like morphologically simplex words such as *Zimmer* 'room' (Lück et al., 2006).

Our experiment tested whether initial, automatic stages of processing provide evidence supporting the postulated distinction between combinatorial -s and unanalyzed -er forms. When we examined facilitation patterns in two age groups combined we observed more facilitation for -s than -er plural forms. This overall difference appears to be mostly due to the contribution of younger adults as older adults produce equally larger priming effects for both plural forms.

In our view, the overall pattern indicating larger facilitation for -er than for -s plural forms might be suggestive of the differences between two forms described above, that is rule-based combinatorial nature of -s forms in contrast to noncombinatorial character of -er forms. In this case, recognition of two plural forms may involve two distinct processes visualized in the Figure 6 (first presented in Chapter 3.2.8) below:

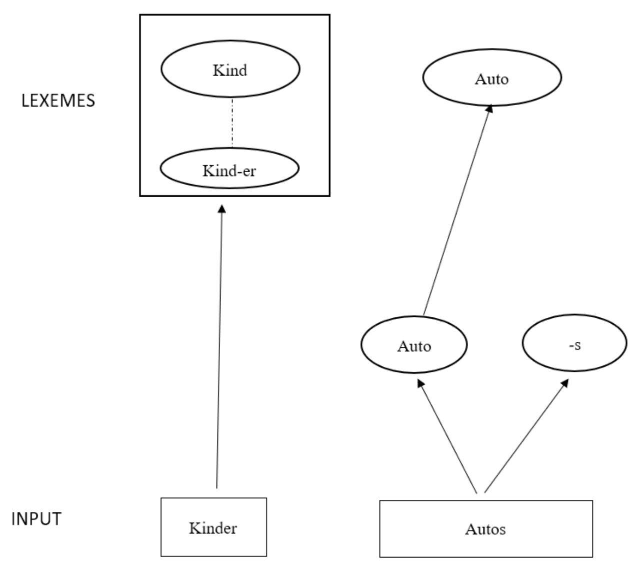

Figure 6. Word-form representations for irregular plural inflected forms (-er forms) and regular plural forms (-s forms)

Under this view, recognition of -s plurals such as *Autos* involves decomposition into the plural affix -s and the base *Auto* with subsequent activation of the target base. In case of -er forms, no decomposition into *Kind* + *er* happens and activation of the target *Kind* is only indirect which would explain a reduced facilitation effect. Priming effect for *Kinder – Kind* is then of the same nature as for *fell – fall* forms in English.

The account suggested earlier draws on the distinction between combinatorial and lexically-stored linguistic units. The question remains whether alternative explanations could also account for the reported findings. It must be acknowledged that this experiment did not include any control sets of semantically or orthographically related items and, hence, one cannot rule out the possibility that observed facilitation effects are not morphological in nature. This possibility seems to us to be unlikely as in other masked priming experiments especially on processing of derived and inflected words in German semantically or orthographically related words have not elicited facilitation effects unlike morphologically related words. Even when some facilitation in control sets as in our experiments on Russian has been observed, it was still largely possible to dissociate robust morphological priming effects from facilitation patterns for only semantically or orthographically related items. Furthermore, semantic relatedness alone cannot account for overall larger facilitation observed for -s than -er forms.

However, one might still wonder whether surface properties of examined words influenced the amount of facilitation. This question is prompted by the fact that some of the -er forms included a stem vowel change (umlaut) as in *Bücher* 'books' – *Buch* 'book'. Upon closer examination it appears that orthographic overlap does not substantially influence priming. First, a separate analysis including the degree of orthographic overlap into the model and its interaction with experimental condition and regularity (-er vs. -s) does not produce a significantly better model than one without this predictor. Second, if we split -er plural forms into two groups with (e.g., *Bücher*) and without umlaut (e.g., *Kinder*) we also find similar facilitation effects and no significant differences between them. These factors may indicate that if orthographic overlap plays a role in the observed differences between -s and -er plural forms it is rather marginal. Furthermore, if surface overlap is expected to cause differences in processing between -er and -s forms in younger adults, it is hard to explain why degree of orthographic overlap becomes less important in older adults as indicated by reduced differences in facilitation effects. All in all, it appears that the larger overlap between related -s primes and targets compared to -er primes and targets cannot fully account for the observed overall differences in priming patterns. The difference in facilitation effects between -er and -s plurals seems to arise mainly due to the distinction between two morphemes and the representations of plural forms.

As mentioned earlier, evidence that the degree of orthographic overlap does not influence recognition of -er plural forms in German and, hence, cannot account for larger priming observed for -s plurals, is partly based on the fact that -er forms with and without umlaut show similar amounts of facilitation. The question arises how this assumption could be reconciled with the claims we made when discussing the processing of Russian verbs with and without allomorphy. In the latter case we attributed the observed difference in facilitation patterns, and specifically larger faciliation for -aj verbs without stem altnernations compared to stems with alternations, to the role of allomorphic changes.

One possible answer to the question as to why the umlaut does not seem to affect processing of -er forms might be that since such forms are presumably irregular and, hence, are retrieved as whole words in contrast to rule-based -s forms, a priming effect is lexically-mediated. We have already compared it to priming effects observed for irregular verbs in English such as *fell – fall*. In this case, however, the degree of the surface overlap should not substantially reduce or increase the amount of facilitation which should be roughly the same for all irregular forms including those with less overlap such as *shake – shook* which were also examined by Crepaldi et al. (2010). The role of allomorphy in Russian could be, however, investigated independently as all tested inflected forms were marked by -u ending which is a typical ending in 1P.Sg. Pr. forms. As a result the observed difference in Russian could not be attributed to the regularity of the whole form.

In essence, Russian verb stems with allomorphic changes and German irregular plural forms are processed via a lexically-mediated mechanism. However, whereas in Russian this mechanism is due to the noncombinatorial nature of the allomorphic stems, in German it is due to the irregularity of the whole form. This explains then why -er forms with orthographic changes and the ones without them are processed in the same fashion since both forms are irregular and therefore stored similarly to forms such as *fell – fall* and *spoke – speak*. Surface differences of the clearly irregular forms as well as the nature of the altnerations are then less important.

Though our results from the study on processing of plural forms in German should be treated with caution, due to the controversies mentioned above, they appear to be in line with the accounts postulating a distinction between forms which are decomposed and which are lexically stored. While this distinction is often observed in experiments tapping into later stages of processing, for example, by Sonnenstuhl et al. (1999), masked priming was usually considered to demonstrate a process of automatic and blind decomposition as arguably demonstrated by Rastle et al. (2004) by *corner – corn* facilitation effects. Note, however, that the study was later criticized by

Baayen et al. (2011) for having also included *fruitless – fruit* type of words. Furthermore, experiments such as by Neubauer and Clahsen (2009) on German regular and irregular participles both of which could be theoretically decomposed (*ge-mach-t* 'done' vs. *ge-schlaf-en* 'slept') and still show a robust contrast in facilitation raise even more doubts concerning automaticity and blindness of decomposition process as observed in masked priming experiments. Therefore, our interpretation of the observed results on processing of German plurals is in line with available experimental evidence.

So far we have examined our data from experiments on Russian and German from a purely linguistic point of view. The results could be summarized in a following way. We interpret our data from both languages as indicating similar processing patterns of derived and inflected forms which is in line with studies on native language processing in contrast to studies testing more challenged populations such as language learners. Additionally, our data from both Russian and German supports an account of morphological processing which posits a contrast between combinatorial and lexically stored items as suggested, for instance, by Clahsen et al. (2003). Inflected forms which are either irregular or show stem alternations appear to be lexically stored in the memory and generally not decomposed into their constituents during the recognition process.

Another research question that was examined in the current work concerns ageing and age-related changes on morphological processing. Ageing is often associated with decline in cognitive abilities and poorer performance across a variety of cognitive tests but only recently researchers have started investigation of possible sources of these changes. However, whereas advanced age is indeed usually linked to losses in terms of cognitive abilities, it is an oversimplification of a far more complex and interesting picture. Some abilities and skills such as memory and processing speed tend to decline, whereas others such as one's vocabulary are generally preserved (Harada, Natelson Love, & Triebel, 2013) or even improve possibly as a result of one's lifelong experience.

Considering this complex interaction of decline and maintenance of cognitive abilities, the question arises whether mechanisms of language processing also remain fully maintained or whether they would be affected by ageing and if so, how. Only a handful of studies have examined mechanisms of morphological processing to find an answer to this question and the obtained data are far from being conclusive. Therefore, we have investigated mechanisms of processing of complex words specifically in older adults including younger adults as a control group.

One set of our findings concerns effects of ageing on general measures of language performance. In fact, these findings appear to be very robust and clear. In all conducted experiments we have observed either longer response latencies (in three experiments) or higher accuracy of older adults. Both measures have been often considered to be a hallmark of ageing. Higher accuracy has been often attributed to larger vocabularies of older adults (Bialystok & Luk, 2012; Burke & Shafto, 2008). Slower reaction times observed in our experiments are frequently found in experiments using lexical decision tasks (Allen, Madden, Weber, & Groth, 1993; Cohen-Shikora & Balota, 2016; Madden, 1992; Ratcliff, Thapar, Gomez, & McKoon, 2004) and often interpreted in favor of the general slowing account of ageing as proposed by Lindenberger and Baltes (1994).

It has been suggested by Ramscar et al. (2014) that age-related richer vocabulary may cause longer response latencies as older adults would then have to search for a word in a significantly larger vocabulary than younger adults which would cost them additional time. Therefore, this approach would expect to find simultaneously longer response latencies and higher accuracy rates. In none of our experiments this was the case. Thus, based on our findings it appears to be unlikely that slowing is necessarily related to larger vocabularies of older adults and higher accuracy rates. Two phenomena may be observed independently from one another in older adults.

A second set of findings from the present dissertation concerns the question of how ageing influences specific aspects of language performance and morphological processing, and specifically mechanisms of word recognition, examined in a series of masked priming experiments. This study shows that more specific aspects of language processing appear to be generally preserved with advancing age. Generally, priming patterns do not differ between older adults and control groups of younger adults. There is, however, potentially a distinction to keep in mind. This difference is between combinatorial and lexically-stored items.

Processing mechanisms involved in comprehension of rule-based combinatorial forms are clearly maintained in older adults as indicated by similar priming patterns observed in two age groups. As an example one could mention -aj verb forms without stem allomorphy in Russian, and -s plural forms in German. The same also applies to derived words in both languages. As hypothesized by Kırkıcı and Clahsen (2013) one mechanism of recognition of such words relies on their decomposition into their morphological constituents. To explain the robustness of this mechanism one may refer to a hypothesis by Ullman (2016) which links decomposition-based processing to the procedural memory which remains relatively intact in ageing. Our findings would thus be in line with existing studies on Hebrew by Kavé and Levy (2004) and Spanish by Duñabeitia et al. (2009) which also found that the ability to decompose morphologically complex words is preserved in older adults.

On the other hand, effects of ageing on processing of units which are presumably non-combinatorial in nature either because they involve complex allomorphy as in Russian or because they are irregular as plural forms in German are less straightforward. Verb forms with stem changes in Russian such as *košu* ‘I mow’ appear to produce equal amount of facilitation in both older and younger adults possibly indicating the involvement of the same lexically-mediated access mechanism. Since recognition of these forms relies on establishing links in the memory between two stems *koš* and *kos,* apparently those links do not show any signs of decline posited by Clahsen and Reifegerste (2017) who would predict weaker memory links between such stems leading to less facilitation. On the other hand, positive effects of lifelong experience and stronger memory links in older adults, as predicted by Reifegerste et al. (2017), are also not observed in our study on Russian.

With regard to processing -er plural forms in German our results are a bit more complicated. Overall facilitation effects for two age groups appear to be similar with more facilitation effects for -s than -er plurals as discussed in detail earlier in this chapter. However, this difference appears to be mainly due to the contribution of younger adults. In older adults facilitation effect for -er nouns becomes somewhat stronger possibly as a result of the lifelong experience. That would be in line with claims made by Reifegerste et al. (2017) who presumed that extra years of experience may actually facilitate a whole-word access in German.

However, the hypothesis by Reifegerste et al. (2017) was originally suggested to account for storage of only plural dominant irregular plural forms in German and also made no distinction between various types of plural forms. Considering that our experiment included only 5 such plural-dominant -er forms out of 30 (e.g., *Kinder* ‘children’) it remains speculative whether the overall stronger facilitation found for -er forms in older adults could be due to the experience-based boost of the whole-word access as according to Reifegerste et al. (2017) all remaining single-dominant plural forms (25 out of 30 -er forms in our experiment) should not be affected in ageing. Even though the account by Reifegerste et al. (2017) suggests increased reliance of older adults on the whole-word access mechanism, it restricts this effect to a very specifically defined set of words and is, therefore, not necessarily compatible with the obtained results in our study. On the whole though our data shows more facilitation in older adults for -er forms possibly due to the experience-based boost of the whole-word access mechanism. It should be stressed, however, that these effects are not very strong.

The present Ph.D. thesis investigated initial, automatic stages of processing of complex polymorphemic words in two languages, that is in Russian and German. This allowed us to investigate phenomena, which are otherwise often neglected in the literature such as properties of stem-formation morphology in Russian. We also examined processing of complex forms in German, which could be classified as being regular (-t participles, -s plural forms) and irregular (-er plural forms). In addition, processing of the phenomena which are similar in both languages, for example, of derived words was also examined. This design allowed us to address the question how various types of morphologically complex words are accessed during the initial stages of processing by means of the masked priming experimental paradigm and also to assess which factors may determine the selection of the processing mechanism.

Among the investigated factors we manipulated the type of the stem (with or without alternations), regularity of the inflected affix, nature of the complex word (derivation vs. inflection). Crucially, we have found out that stem types (with or without alternation) influence morphological processing such that complex forms without alternations are most likely either fully decomposed or their stems preserve morphological structure, whereas allomorphic stems are looked up in the mental lexicon and are accessed via a lexically-mediated mechanism. Our findings from German likely indicate similar patterns with regard to the processing of regular -s and irregular -er plural forms. Interestingly, the nature of the word itself (derived or inflected) has not visibly influenced initial stages of processing in neither Russian nor German which is more similar to findings from studies on processing in native speakers and not challenged groups such as language learners.

Another aspect of morphological processing which was investigated in the present research project was the role of age-related changes. Due to the cognitive changes often associated with ageing and especially the generally assumed cognitive decline of many skills and abilities, it was unclear whether morphological processing mechanisms would remain fully intact in the older adults or show signs of age-related changes.

Our data suggests that future studies should differentiate between general aspects of language performance and more subtle ones relevant for specific mechanisms of morphological processing. The former ones clearly indicate effects of ageing specifically on overall RTs and accuracy scores of lexical decisions which may be caused by neuro-cognitive decline and/or more experience with the language due to longer exposure at older age. By contrast, the specific aspects of morphological processing appear to be extremely robust and are apparently preserved in older adults. This is especially clear in case of the recognition mechanisms of complex forms which are combinatorial in nature. With regard to the processing of forms which are presumed to be lexically stored our study has not found consistent evidence to support claims about substantial age-related changes either even though some findings (e.g., more facilitation for irregular plural forms in older adults) could be taken to indicate the role of lifelong experience and exposure. Yet, this effect appears to be very subtle in the present study and should be further investigated in the future.

Based on the findings from our study, one may presume that morphological processing as investigated by means of a series of masked priming experiments appears to be generally unaffected by ageing. However, the question arises whether this is indeed the case or whether participants tested in the present study were, perhaps, simply not old enough for the effects of ageing to become visible. Considering that older adults tested in this study were on average 66-67 years old and taking into account that cognitive decline is claimed to be already visible at the age of 45-49 (Singh-Manoux et al., 2012), this explanation appears to problematic. However, timing of onset of cognitive decline remains a controversial issue as according to the data from longitudinal studies it begins later at about the age of 60 (Hedden & Gabrieli, 2004; Nilsson, Sternäng, Rönnlund, & Nyberg, 2009). Under this assumption, it could be claimed that participants tested in the present study were not much affected by cognitive decline yet. This possibility should not be disregarded taking into account that especially highly automatic processes show very small effects of age-related changes until late in life (Hedden & Gabrieli, 2004). Considering that the masked priming technique is assumed to tap precisely into automatic and unconscious stages of word processing, it might be possible that age-related effects could be observed only much later, for instance, at the age of 80 when effects of cognitive decline become more pronounced. Future research needs to examine this possibility.

An even more important question is whether results obtained in this study showing largely similar facilitation patterns in older and younger adults necessarily imply absence of substantial age-related changes. Studies comparing behavioural and neuroimaging or neurophysiological data often demonstrate that "absence of behavioral change does not necessarily mean an absence of neural change" (Tyler et al., 2010, p. 352). Such studies have examined a range of phenomena, including syntactic processing and sentence comprehension (Tyler et al., 2010; Wingfield & Grossman, 2006), spoken comprehension of concrete and abstract words including processing advantage for concrete words (Roxbury, McMahon, Coulthard, & Copland, 2016); incidental or intentional learning and recognition of words (van der Veen, Nijhuis, Tisserand, Backes, & Jolles, 2006); repetition priming tested by means of a stem-completion task[21] (Osorio, Fay, Pouthas, & Ballesteros, 2010) or by

[21] Participants are presented with target words and after a pause with three-letter word stems which should be completed to form a word (e.g. *WIN* - *WINDOW)*. Some of the stems are new while some are from the previously presented list

means of semantic (living vs. nonliving classification of new and previously shown words) repetition priming (Lustig & Buckner, 2004); sublexical, orthographic, phonological and lexico-semantic processing (Froehlich et al., 2018) etc. While behavioral data in the studies above is similar in both groups, neuroimaging data often reveal differences with respect to brain activation patterns between older and younger adults. The neuroimaging data often show more activity in frontal regions with advancing age and/or recruitment of additional brain regions especially in the contralateral hemisphere in older adults (Cabeza, Anderson, Locantore, & McIntosh, 2002; Lustig & Buckner, 2004; Tyler et al., 2010).

The pattern described above has been often used to argue in favor of the compensation hypothesis. Increased activation presumably compensates for age-related cognitive decline and allows older adults to often preserve the similar level of functional performance shown by younger counterparts (Cabeza, 2002; Cabeza et al., 2002). It could be claimed that behavioral measures are less sensitive to age-related changes than neurofunctional measures (Daselaar, Veltman, Rombouts, Raaijmakers, & Jonker, 2005). Therefore, equivalent behavioral performance across two age groups could be a result of effective neural reorganization in older adults and should not be taken to indicate absence of underlying age-related changes (Tyler et al., 2010). In the light of the above-mentioned claims future studies should rely not only on behavioural but also on neuroimaging or neurophysiological data in order to examine potential age-related changes with respect to morphological processing of complex words.

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6 Appendices

Appendix A

Critical items in experiment on derivation in Russian

	Test primes		Targets	Translation
Derived Items	hrabrost‘	zhivot	hrabryj	bravery – belly – brave
	shchedrost‘	obida	shchedryj	generosity – offence – generous
	grubost‘	svad'ba	grubyj	rudeness – wedding – rude
	trezvost‘	pidzhak	trezvyj	sobriety – jacket – sober
	sytost‘	mysh	sytyj	fullness – mouse – full (with food)
	gordost‘	vedro	gordyj	pride – bucket – proud
	ploskost‘	blesk	ploskij	flatness – shine – flat
	tupost‘	tetrad'	tupoj	stupidity – exercise book – stupid
	zhivost‘	gnezdo	zhivoj	livelihood – nest – lively
	molodost‘	shuba	molodoj	youth – fur coat – young
	hrupkost‘	krysa	hrupkij	fragility – rat – fragile
	jasnost‘	meh	jasnyj	clarity – fur – clear
	naglost‘	mest'	naglyj	audacity – revenge – audacious
	polost‘	lipa	polyj	hollowness – linden – hollow
	glupost‘	uksus	glupyj	foolishness – vinegar – foolish
	veselost‘	metel'	veselyj	hilarity – snow storm – hilarious
	junost‘	chesnok	junyj	juvenility – garlic – juvenile
	prjanost‘	vishnja	prjanyj	spice – cherry – spicy
	slabost‘	goroh	slabyj	weakness – pea – weak
	blednost‘	chehol	blednyj	paleness – case – pale
	starost‘	tvorog	staryj	old age – cottage cheese – old
	musdrost‘	izjum	mudryj	wisdom – raisins – wise
	milost‘	basnja	milyj	(your) highness – fable – nice
	syrost‘	mechet'	syroj	moisture – mosque – moist
	zlost’	bobjor	zloj	anger – beaver – angry

	hitrost’	shurup	hitryj	cunning – screw – tricky
	novost’	sljakot'	novyj	piece of news – slush – new
	tverdost’	baton	tverdyj	hardness – baguette – hard
	malost’	pavlin	malyj	small thing – peacock – small
	suhost’	losos'	suhoj	dryness – salmon – dry
	Test primes	**Control primes**	**Targets**	**Translation**
Semantically related items	pochva	rubezh	zemla	ground – frontier – land
	seno	zarja	soloma	hay – dawn – straw
	krolik	moneta	zajac	rabbit – coin – hare
	par	gnev	dym	steam – anger – smoke
	knjaz‘	ryba	korol‘	prince – fish – king
	zhena	put‘	muzh	wife – path – husband
	arbuz	akula	dynja	watermelon – shark – melon
	uzhas	kreslo	strah	horror – armchair – fear
	utro	syn	vecher	morning – son – evening
	koza	tropa	ovtsa	goat – footpath – sheep
	okno	semja	dver‘	window – family – door
	serebro	perec	zoloto	silver – pepper – gold
	plamja	kovjor	ogon‘	flames – carpet – fire
	pishcha	bashnja	eda	nourishment – tower – food
	pechal‘	petlja	grust‘	grief – loop – sadness
	remen‘	znamja	pojas	leather belt – banner – belt
	kofta	shchi	sviter	woolen jacket – cabbage soup - pullover
	plashch	mjach	pal’to	raincoat – ball – coat
	ruchej	chetverg	reka	stream – Thursday – river
	sneg	zub	dozhd‘	snow – tooth – rain
	zavtrak	ruzhje	uzhin	breakfast – shotgun – supper
	Test primes	**Control primes**	**Targets**	**Translation**
Orthographically related items	related	items	tarakan	to crash – to break down – cockroach
	horonit‘	voskresit‘	horoshij	to bury – to resurrect – good

molchat‘	krichat‘	moloko	to keep silent – to shout – milk
medved‘	bassejn	meduza	bear – swimming pool – jellyfish
stakan	ekran	stado	glass – screen – flock
holostoj	materyj	holod	single – hardened – cold
morochit‘	upovat‘	moroz	to trick – to trust – frost
svekrov‘	testo	svekla	mother-in-law – dough – beetroot
porochit‘	bryzgat‘	porog	to discredit – to splash – threshold
golod	zhaloba	golos	hunger – lament – voice
storozhit‘	pishchat‘	storona	to guard – to pip – side
korobit‘	pjanet‘	korova	to offend – to get drunk – cow
poloskat‘	vershit‘	polosa	to rinse – to accomplish – a stripe
beredit‘	tormoshit‘	bereg	to irritate – to bother – coast
skrizhal‘	tjulen‘	skrip	tablet (of commandments) – seal – squeak
koleso	palata	koleno	wheel – ward – knee
strast‘	nozh	strana	passion – knife – country
gorshok	almaz	gora	pot – diamond – mountain
kormit’	zhalet’	kora	to feed – to regret – bark (of a tree)
boronit’	zabavljat’	boroda	to harrow – to amuse – beard
streljat’	guljat’	strekoza	to shoot – to go for a walk – dragonfly

Appendix B

Critical items in experiment on inflection in Russian

Item type	Test primes	Control primes	Targets	Translation (control primes - targets)
Verbs without stem changes (-aj verbs)	poluchaju	ozhidaju	poluchat'	expect - get
	meshaju	zhelaju	meshat'	disturb / stir - wish
	streljaju	padaju	streljat'	fall - shoot
	begaju	mechtaju	begat'	dream - run
	brosaju	puskaju	brosat'	allow / permit - throw
	terjaju	guljaju	terjat'	walk - loose
	stiraju	migaju	stirat'	blink - wash
	veshaju	dergaju	veshat'	pull - hanff
	polzaju	mercaju	polzat'	shimmer - crawle
	pomogaju	obeshchaju	pomogat'	promise - help
	skuchaju	kidaju	skuchat'	throw - miss
	reshaju	letaju	reshat'	fly - solve
	plavaju	shagaju	plavat'	stride - swim
	lomaju	kivaju	lomat'	nod - break
	menjaju	prygaju	menjat'	jump - change
	boltaju	spasaju	boltat'	rescue - chatter
	hlopaju	pugaju	hlopat'	scare - clap
	rugaju	stupaju	rugat'	tread - scold
	kachaju	vedaju	kachat'	know - swing
	sazhaju	tolkaju	sazhat'	push - plant
	sverkaju	kushaju	sverkat'	eat - glitter
Verbs with stem changes (-i verbs)	noshu	horonju	nosit'	bury - wear / carry
	stavlju	sluzhu	stavit'	serve - set
	suzhu	varju	sudit'	cook - judge
	slezhu	ezzhu	sledit'	drive / travel - watch/spy
	kachu	kurju	katit'	smoke - roll
	gotovlju	grozhu	gotovit'	threaten - prepare/cook
	lovllu	vozhu	lovit'	drive - catch
	kormlju	davlju	kormit'	crush - feed
	shuchu	tverzhu	shutit'	repear - joke
	brozhu	rasshchu	brodit'	raise / rear - roam
	trachy	speshu	tratit'	hurry - spend
	kruchu	zharju	krutit'	roast - twist
	glazhu	tashchu	gladit'	drag - iron
	chishchu	koshchu	chistit'	reprimand - clean

Item type	Test primes	Control primes	Targets	Translation
	skolzhu	muchu	skolzit'	torment - glide
	norovlju	trevozhu	norovit'	disturb - strive
	buzhu	darju	budit'	present - wake
	rublju	hvalju	rubit'	praise - chop
	porchu	druzhu	portit'	be friends - spoil
	koshu	lechu	kosit'	heal - mow
	proshu	hozhu	prosit'	walk - ask
Verbs with stem changes (idiosyncratic verbs)	begu	gljazhu	bezhat'	look - run
	edu	verju	ehat'	believe - ride
	zovu	kolju	zvat'	stab - call
	pju	zvuchu	pit'	sound - drink
	bju	shju	bit'	sew - beat
	shlju	roju	slat'	dig - send
	poju	zhmu	pet'	press - sing
	plyvu	strigu	plyt'	cut - swim
	gonju	ishchu	gnat'	seek - chase, hurry
	kladu	plachu	klast'	cry - put
	teku	mashu	tech	wave - leak
	beregu	bormochu	berech	mutter - protect
	vedu	prjachu	vesti	hide - lead, conduct
	vju	hohochu	vit'	laugh - weave
	noju	rezhu	nyt'	cut - whine
	bredu	shepchu	bresti	whisper - stroll
	lju	dremlju	lit'	drowse - pour
	pru	pljashu	peret'	dance - make one' way
	voju	skachu	vyt'	ride - howl
	zhgu	hlopochu	zhech	bustle about - burn
	tru	splju	teret'	sleep - rub

Item type	Test primes	Control primes	Targets	Translation
Orthographically related words	vrag	partija	vrach	enemy - party - doctor
	rot	chistyj	rota	mouth - clean - company (military)
	krasivyj	hudoj	kraj	beautiful - slim - edge
	ostrov	plan	ostryj	island - plan - sharp
	golod	krug	golyj	hunger - circle - nude
	pjostryj	kust	pjos	motley - bush - dog
	smelyj	rano	smena	brave - early - shift
	vnutr'	palka	vnuk	insude - stick - grandson

	gluboko	kol'co	gluhoj	deep - ring - deaf
	pochka	skazka	pochva	bud/kidney - tale - soil
	ris	gruz	risovat'	rice - cargo - paint
	grust'	kabluk	grusha	sadness - hell - pear
	parus	dvesti	parta	sail - 200 - bench
	korol'	pero	korotkij	kind - feather - short
	ploshchad'	brak	ploho	square - marriage/waste - bad
	stranno	plod	strah	strange - fruit - fear
	slava	rezat'	slabyj	glory - cut -weak
	holm	kosa	holod	hill - braide/saithe - cold
	grom	ikra	grob	thunder - caviar - coffin
	stuk	blin	stul	knock - pancake - chair
	kategorija	halat	kater	category - robe - cutter
Semantically related words	magazin	sklon	ochered'	shop - slope - queue
	nadezhda	podushka	vera	hope - pillow - faith
	trubka	zapah	telefon	receiver - smell - telephone
	roman	kuhnja	rasskaz	novel - kitchen - story
	institut	dobryj	nauka	instutue - good - science
	oruzhije	polovina	boj	weapon - half - battle
	baba	centr	ded	woman - center - grandfather
	cvetok	stol'ko	list	flower - so much - leaf
	radost'	sto	ulybka	joy - one hundred - smile
	shchit	spasibo	mech	shield - thanks - sword
	ohotnik	spokojno	ruzhjo	hunter - calmly - rifle
	zhenih	moguchij	svad'ba	groom - mighty - wedding
	krolik	ranenyj	zajac	rabbit - wounded - hare
	iskra	svedenije	plamja	spark - piece of information - flame
	patron	davlenije	snarjad	bullet - pressure - shell
	sudno	svidanije	morjak	ship - rendezvous - sailor
	papirosa	stremlenije	spichka	cigarette - ambition - match
	chashka	granata	posuda	cup - grenade - utensil
	konvert	prestupnik	pochta	envelope - criminal -post
	mylo	lavina	polotence	soap - avalanche - towel
	osjol	resurs	baran	donkey - resource - ram

Appendix C

Critical items in experiment on derived and inflected words in German

Morphological Items							
Derived prime		Inflected prime		Unrelated prime		Target (Inf)	
Änderung	'change'	geändert	'changed'	klein	'small'	ändern	'change'
Äußerung	'utterance'	geäußert	'uttered'	Teufel	'devil'	äußern	'utter'
Bohrung	'drilling'	gebohrt	'drilled'	Pfanne	'pan'	bohren	'drill'
Drehung	'rotation'	gedreht	'turned'	Teppich	'carpet'	drehen	'turn'
Drohung	'threat'	gedroht	'threatened'	schräg	'crooked'	drohen	'threaten'
Ehrung	'distinction'	geehrt	'honored'	Dampf	'steam'	ehren	'honor'
Forderung	'request'	gefordert	'demanded'	Artikel	'article'	fordern	'demand'
Führung	'leadership'	geführt	'led'	Brief	'letter'	führen	'lead'
Fütterung	'feeding'	gefüttert	'fed'	Scheune	'barn'	füttern	'feed'
Kündigung	'written notice'	gekündigt	'discharged'	Batterie	'battery'	kündigen	'give notice'
Kürzung	'reduction'	gekürzt	'shortened'	Storch	'stork'	kürzen	'shorten'
Lenkung	'steering'	gelenkt	'steered'	privat	'personal'	lenken	'steer'
Lieferung	'delivery'	geliefert	'delivered'	scharf	'sharp'	liefern	'deliver'
Lösung	'solution'	gelöst	'solved'	knapp	'scarce'	lösen	'solve'
Öffnung	'opening'	geöffnet	'opened'	streng	'strict'	öffnen	'open'
Prüfung	'check'	geprüft	'checked'	Spiegel	'mirror'	prüfen	'check'
Rettung	'rescue'	gerettet	'rescued'	schwarz	'black'	retten	'rescue'
Sammlung	'collection'	gesammelt	'collected'	hübsch	'pretty'	sammeln	'collect'
Schenkung	'gift'	geschenkt	'given (gift)'	Knochen	'bone'	schenken	'make a gift'
Sicherung	'safeguarding'	gesichert	'secured'	Fleisch	'meat'	sichern	'secure'
Steigerung	'increase'	gesteigert	'increased'	Flasche	'bottle'	steigern	'increase'
Störung	'disruption'	gestört	'disturbed'	frisch	'fresh'	stören	'disturb'
Täuschung	'deception'	getäuscht	'deceived'	schlank	'slim'	täuschen	'deceive'
Trennung	'separation'	getrennt	'separated'	schlimm	'bad'	trennen	'separate'
Übung	'practice'	geübt	'practised'	Wolf	'wolf'	üben	'practise'
Wanderung	'hike'	gewandert	'hiked'	komplett	'complete'	wandern	'hike'
Warnung	'warning'	gewarnt	'warned'	flach	'flat'	warnen	'warn'
Weigerung	'refusal'	geweigert	'refused'	kaputt	'broken'	weigern	'refuse'

Orthographically related items					
Related primes		Unrelated primes		Targets	
Apfel	'apple'	Knopf	'button'	Fell	'fur'
brauchen	'to require'	schreiben	'to write'	tauchen	'to dive'
denken	'to think'	hören	'to hear'	danken	'to thank'

Engel	‘angel’	Stirn	‘forehead’	Geld	‘money’
Eule	‘owl’	Pilz	‘mushroom’	heulen	‘to wail’
grinsen	‘to grin’	stinken	‘to stink’	Insel	‘island’
Kartoffel	‘potato’	Petersilie	‘parsley’	Karte	‘card, map’
Kasten	‘box, chest’	Schwan	‘swan’	Kasse	‘cash register’
löschen	‘to extinguish’	trösten	‘to comfort’	Scheck	‘check’
Regel	‘rule’	Prinz	‘prince’	Regen	‘rain’
reiten	‘to ride’	malen	‘to paint’	Reise	‘journey’
Schachtel	‘case, box’	Trompete	‘trumpet’	Schal	‘scarf’
Schaf	‘sheep’	Biene	‘bee’	schaffen	‘to accomplish’
schauen	‘to look’	lächeln	smile’	Haus	‘house’
schlafen	‘to sleep’	zwingen	force’	Schlange	‘snake’
schneiden	‘to cut’	flüchten	‘to flee’	Schnee	‘snow’
Schule	‘school’	Technik	‘technology’	Schuh	‘shoe’
schweigen	‘to be silent’	springen	‘to jump’	Wein	‘wine’
Schwein	‘pig’	Schmutz	‘dirt’	weinen	‘to cry’
schwindeln	‘to swindle’	schnarchen	‘to snore’	Wind	‘wind’
sprechen	‘to speak’	finden	‘to find’	rechnen	‘to calculate’
Tante	‘aunt’	Sturm	‘storm’	Tanne	‘firtree’
Tasche	‘bag’	Stoff	‘fabric’	Tasse	‘cup’
Wache	‘guard’	Alarm	‘alarm’	wachsen	‘to grow’
Semantically related items					
Related primes		**Unrelated primes**		**Targets**	
Banane	‘banana’	Forelle	‘trout’	Affe	‘monkey’
Bild	‘picture’	Land	‘country’	Foto	‘photo’
Boot	‘boat’	Burg	‘castle’	Schiff	‘ship’
Doktor	‘doctor’	Presse	‘press’	Arzt	‘physician’
Frau	‘woman’	Teil	‘part’	Mann	‘man’
Gardine	‘curtain’	Gazelle	‘gazelle’	Vorhang	‘curtain’
Gürtel	belt’	Sperre	‘barricade’	Hose	‘pants’
Herd	‘stove’	Kuss	‘kiss’	Ofen	‘oven’
Hut	‘hat’	Lob	‘praise’	Mütze	‘cap’
Kirche	‘church’	Woche	‘week’	Gebet	‘prayer’
Krawatte	‘tie’	Passage	‘passage’	Schlips	‘tie’
Matrose	‘sailor’	Tablette	‘tablet’	pill’	Seemann
Motor	‘engine’	Name	‘name’	Auto	‘car’
Soldat	‘soldier’	Etappe	‘stage’	Krieg	‘war’
Stadt	‘city’	Grund	‘reason’	Dorf	‘village’
Tisch	‘table’	Licht	‘light’	Stuhl	‘chair’
Tonne	‘barrel’	Wiese	‘meadow’	Fass	‘barrel’

Truhe	‘chest, box’	Ampel	‘traffic light’	Kiste	‘box’
Vase	‘vase’	Nonne	‘nun’	Blume	‘flower’
Wolke	‘cloud’	Kunde	‘customer’	Himmel	‘sky’
Wüste	‘desert’	Zitat	‘quote’	Sand	‘sand’
Zeit	‘time’	Herr	‘mister’	Uhr	‘clock’
Zug	‘train’	Hof	‘yard, court’	Bahn	‘lane’
Zweig	‘twig branch’	Wucht	‘impact’	Baum	‘tree’

Appendix D

Critical items in experiment on plural nouns in German

-s Plurals			
Related	**Unrelated**	**Target**	**Translation (unrelated-target)**
Kolibris	Fabeltier	Kolibri	mythical creature - hummingbird
Tombolas	Aspirin	Tombola	aspirin- lottery
Gorillas	Edelweiß	Gorilla	edelweiss- gorilla
Flamingos	Schaufel	Flamingo	shovel - flamingo
Lassos	Besteck	Lasso	cutlery - lasso
Kartons	Spalier	Karton	espalier, trellis - box
Briketts	Brauerei	Brikett	brewery - briquet
Festivals	Einreise	Festival	entry - festival
Tips	Begrüßung	Tip	welcome - hint
Zebras	Ertrag	Zebra	output, crop - zebra
Albinos	Beschattung	Albino	shading - albino
Lampions	Fahrschule	Lampion	driving school - lantern
Fiaskos	Aspirin	Fiasko	aspirin - failure
Ponys	Eskorte	Pony	escort - pony
Dias	Klausel	Dia	clause - slide
Salons	Moped	Salon	moped - salon
Decks	Hirte	Deck	shepherd - deck
Apartments	Naturell	Apartment	nature - flat
Studios	Neuschnee	Studio	snow - tudio
Kinos	Ortschaft	Kino	village - cinema
Embargos	Allergie	Embargo	allergy - embargo
Pullis	Auflauf	Pulli	casserole - sweater
Moskitos	Molekül	Moskito	molecule - mosquito
Safaris	Baldrian	Safari	valerian - safari
Kobras	Florett	Kobra	foil - cobra
Bonbons	Register	Bonbon	register - sweet
Omas	Giebel	Oma	gable - grandma
Kommandos	Mythos	Kommando	myth - command
Details	Chaos	Detail	chaos - detail
Echos	Hefe	Echo	yeast - echo
-er Plurals			
Blätter	Flasche	Blatt	bottle - leaf
Altertümer	Harlekin	Altertum	harlequin - antiquity
Nester	Satire	Nest	satire - nest
Kälber	Limousine	Kalb	sedan - calf

Gewänder	Lohntüte	Gewand	wage packet - robe
Denkmäler	Neufassung	Denkmal	revised form - monument
Rinder	Daumen	Rind	thumb - cow
Löcher	Broschüre	Loch	brochure - hole
Bücher	Debatte	Buch	debate - book
Kinder	Mittwoch	Kind	Wednesday - child
Räder	Nordsee	Rad	north sea - wheel
Sträucher	Kanzel	Strauch	pulpit - bush
Körner	Nachtrag	Korn	addendum, amendement - grain
Gespenster	Lebensart	Gespenst	lifestyle - ghost
Fässer	Plasma	Faß	plasma - barrel
Hörner	Kontrast	Horn	contrast - horn
Reichtümer	Müdigkeit	Reichtum	fatigue - riches
Eier	Flasche	Ei	bottle - egg
Ämter	Einkauf	Amt	purchasing - office
Männer	Fernsehen	Mann	television - man
Lämmer	Ferse	Lamm	heel - lamb
Hölzer	Monolog	Holz	monologue - wood
Würmer	Abglanz	Wurm	reflection - worm
Gemüter	Befugnis	Gemüt	authorization - mind, temper
Kräuter	Anprobe	Kraut	fitting - herb
Hühner	Diener	Huhn	servant - chicken
Gräser	Kantate	Gras	cantata - grass
Dächer	Mikrofon	Dach	microphone - roof
Mitglieder	Technik	Mitglied	technology - member
Bilder	Flugzeug	Bild	plane - picture