Inflectional Suffix Priming in Czech Verbs and Nouns

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Abstract

Two experiments examined if processing of inflectional affixes is affected by morphological priming, and whether morphological decomposition applies to inflectional morphemes in visual word recognition. Target words with potentially ambiguous suffixes were preceded by primes that contained identical suffixes, homophonous suffixes with different function, or different suffixes. The results partially confirmed the observation that morphological decomposition initially ignores the affix meaning. With verb targets and short stimulus-onset asynchrony (SOA), homophonous suffixes had similar effects as identical suffixes. With noun targets, there was a tendency to respond faster after homophonous targets. With longer SOA in verb targets, the primes with identical suffix resulted in shorter responses than the primes with a homophonous suffix. Similar tendency was observed in some noun targets. The results confirm that it is possible to prime inflectional affixes, but that the mechanisms of morphological analysis may operate differently for different types of affixes.

Keywords: morphological priming, affix priming, word recognition, morphological decomposition, inflection

Introduction

Numerous studies suggested that morphologically complex words are decomposed to individual morphemes during visual word recognition. Most evidence for decomposition comes from priming studies, in which morphologically related words are presented in succession. Repeating the same morpheme in both the first word (prime) and the subsequent word (target) results in faster processing of the targets, as measured for instance by the lexical decision task.

The effects of morphological priming have been established first with words that overlapped in their root morphemes. Words consisting of roots and affixes have been shown to prime their roots (*friendly-friend*), as well other words derived from the same roots (*confession-confessor*, see e. g. Marslen-Wilson, Tyler, Waksler, & Older, 1994). This work established that word roots are accessed during the processing of morphologically complex words. If this is the case, functional morphemes should be accessed as well, and it should be possible to prime the access to these morphemes.

Priming of affixes proved more challenging than priming of word roots. Some studies found priming effects between words sharing prefixes, such as *dislike-disprove*. These effects were stronger than if there was mere orthographic overlap in the word initial segments, e. g. in *uncle-unhappy* (e. g. Chateau, Knudsen, & Jared, 2002; Giraudo & Graigner, 2003). While the findings with prefixes are quite robust, suffix priming has been more difficult to establish. (Marslen-Wilson, Ford, Older, & Zhou, 1996) found evidence for priming between auditory primes and visual targets that shared derivational suffixes (*darkness-toughness*). However, some research suggested that only prefixes could be primed, but not suffixes (Giraudo & Graigner, 2003).

Recently, Duñabeitia, Perea, and Carreiras (2008) were able to show affix priming in suffixed Spanish words. Their participants processed the suffixed words faster if they were preceded by words with the same suffixes. The effect was also present when the primes contained isolated suffixes only, or suffixes attached to strings of non-letter characters.

The literature thus indicates that affixes can be primed, even though there may be differences between prefixes and suffixes in the susceptibility to priming. However, all research sketched above worked with derivational affixes. It is not clear whether inflectional affixes are susceptible to morphological priming as well. Given that some languages have rich inflectional morphology and that many words in these languages appear with some inflection, the question about affix priming is highly relevant.

Early vs. late decomposition

The available evidence suggests that morphological decomposition of printed words proceeds by first removing all potential affixes and subsequently checks if this decomposition is the correct analysis. So, Rastle, Davis, and New (2004) showed that *brother* can prime *broth*, even though *brother* is not composed of the morphemes *broth+er*. Longtin, Segui, and Halle (2003) speak about *pseudo-derivation* in this context and show that pseudo-derived words may prime words that seem related to them. The meaning-blind early morphological decomposition may be responsible for the difficulties in detecting suffix priming. Duñabeitia et al. (2008) suggested that early decomposition is responsible for the lack of affix priming effects reported by Giraudo and Graigner (2003). Their study compared morphologically related primes (e. g. *fumet-MURET*) or orthographic control primes (*béret-MURET*). It is possible that the orthographic control primes were initially decomposed even though their final segment (*-et*) is not a true suffix. Because of this decomposition, Giraudo and Graigner (2003) did not detect any difference between these conditions. The evidence thus suggests that early stages of morphological decomposition ignore the meaning of affixes. If two homophonous affixes with different function are presented, they should initially have the same impact on the processing of subsequent words.

Current study

The present experiments explored whether the processing inflectional affixes in Czech nouns could be affected by morphological priming. Of particular interest was the issue of homophonous affixes and the process of their interpretation.

Participants saw suffixed target words. These targets were preceded with visual primes. In the two key conditions, the prime words ended in a suffix with the same phonetic form as the suffix in the target words. However, in one of these conditions, this suffix was fully identical to the target suffix, i. e. shared both its phonetic form and its function. In the other condition, the prime word contained a homophonous suffix with a different function.

The basic prediction was that the homophonous morphemes should have similar effects as the identical morphemes in masked priming with short stimulus-onset asynchrony. In unmasked priming, i. e. with longer SOA, suffix with identical function should result in stronger priming effects than the homophonous suffix that merely shares the form but not the function of the target suffix. Experiment 1 tested the prediction for short SOA, Experiment 2 for longer SOA. Each experiment involved two components, one with nouns and one with verbs as target words. The noun component of involved two additional conditions, the baseline, and a condition involving a prime suffix with different form but the same function as the target. The verb component only used primes in the two conditions with homophonous affixes.

Experiment 1

All target words in each component ended with potentially ambiguous suffix. In the noun targets, this was one of the Czech feminine nominative suffixes, *-a*. In the two key conditions, the primes also ended with *-a*. In the identical condition, the primes were feminine nominatives, in the homophone conditions, they were masculine accusatives/genitives. With regard to these two conditions, the prediction was that there would not be no difference between lexical decision times on target nouns. With 50 ms latency, the primes should be decomposed and suffixes identified by the time of target presentation, but the function of the suffixes should not be accessed yet. In order to test whether decomposition occurred at all, a condition with orthographically distinct nominative suffix primes was introduced in the noun component (no such controls were possible for the verbs). Reaction times in this allomorph condition should be slower because the search for the target suffix will not have started until the target is presented. The baseline condition served to establish the processing times for target target words with no primes.

The verb component focused narrowly on the comparison of the identical and homophone suffixes. No differences in the effect of these suffixes were predicted in Experiment 1.

Method

Stimuli The noun component contained 104 experimental items in four conditions summarized in Table 1. Four versions of the protocol were created so that each target word was presented in each condition to approximately the same number of participants. The verb component of the experiment presented 26 target words in two conditions: primes had either the same suffix, or a homophonous suffix. The verb component did not contain the baseline condition, nor the different-suffix condition. This was mainly because the number of possible stimuli was much smaller. Two versions of the verb component were created and presented to approximately equal number of participants, so that each target word was presented in each condition to equal number of participants. All the experimental conditions were constructed so that the prime and target words had approximately equal frequency, and that in each version of the protocol, the mean frequency of the primes and targets was approximately equal. The primes and targets always had the same number of letters. Primes were presented in uppercase, targets in lowercase letters.

Table 1: Sample stimuli from all conditions

	Condition	Prime	Target
Noun targets	baseline	XXXX	váha
	identical	LÍPA	váha
	homophone	SYNA	váha
	allomorph	VŮLE	váha
Verb targets	identical	BERETE	žijete
	homophone	KUŘETE	žijete

Besides the 140 experimental trials, 123 real word fillers and 270 nonword fillers were presented. The presentation was block-randomized so that trials from different conditions occurred with approximately equal probability during the whole experiment.

Pariticipants Thirty-nine students participated in the experiment as a part of their course requirement. All were native speakers of Czech.

Procedure The experiment was presented on a laptop computer using DMDX (Forster & Forster, 2003) as the presentation and response-collection software. Each trial started with a fixation cross presented for 500 ms. Then, the prime word was presented for 50 ms, followed by the subsequent presentation of the target word. The target word was shown until response was made or until 1500 ms from the onset. If no response was made within 1500 ms, the no response was recorded and the computer proceeded to the next trial.

Analysis The data were analyzed using linear mixed models with random effects for persons and items. This procedure replaces the separate ANOVA analyses by subjects and items (cf. Baayen, Davidson, & Bates, 2008). Post-hoc pairwise comparisons used the Tukey method as implemented in the `multcomp` package for R (R development core ceam, 2003).

Results

Results are summarized in Table 2. The initial analysis compared the reaction times in the experimental conditions to the baseline using planned contrasts. Compared to the baseline, reaction times were significantly longer in the nominative allomorph (*-e*) condition ($t = 3.55$, $p < 0.001$). In the identical (nominative *-a*) condition, the times were also slower and

Table 2: Top: baseline reaction times and the effects in experimental conditions. Bottom: pairwise comparisons of reaction times in experimental conditions. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$

	SOA	
	50 ms	150 ms
Baseline	664	667
Nom. -a (identical)	*10	*13
Acc. -a (homophone)	2	***20
Nom -e (allomorph)	**17	*12

	50 ms	150 ms
Identical − homophone	8	7
Identical − allomorph	-7	-1
Homophone − allomorph	*15	-8

Table 3: Top: baseline reaction times and the effects in experimental conditions, separately for short and long nouns. Bottom: pairwise comparisons of reaction times in experimental conditions. **$p < 0.01$, *$p < 0.05$, †$p < 0.10$

	SOA			
	50 ms		150 ms	
Word length (letters)	4–6	7	4–6	7
Baseline	658	672	668	666
Nom. -a (identical)	*17	1	8	*19
Acc. -a (homophone)	6	-3	*17	**25
Nom -e (allomorph)	**19	*15	*18	4

	50 ms		150 ms	
Identical − homophone	11	4	-9	-6
Identical − allomorph	-2	-14	-10	15
Homophone − allomorph	-13	†-18	-1	*21

the difference was significant ($t = 2.01$, $p = 0.048$). There was no significant difference between the baseline and the incongruent homophonous (accusative *-a*) suffix condition ($t = 0.46$, $p = 0.67$). Post-hoc analysis using Tukey contrasts revealed a significant difference between the accusative homophonous condition and the nominative allomorph condition ($p = 0.01$). There was no significant difference between the congruent condition and the incongruent or allomorph condition.

The prediction for the experiment was that there should be no difference between the congruent and incongruent condition. This is in line with the results. However, both these conditions should be faster than the allomorph condition. This is only true about the incongruent condition. In order to examine this discrepancy, an analysis was performed that divided the items according to their length. It may be the case that the shorter prime words were processed to a larger extent that the longer primes. If there are any differences between shorter and longer words, the original prediction should be valid for the longer words, that were presumably processed to a lesser extent, In shorter words, differences between the two key conditions may surface because the prime suffix has been processed enough so that its function is being accessed.

Two analyses were performed separately for two groups. One group consisted of stimuli with 4-, 5- and 6-letter words (57 trials), the other group of stimuli with 7-letter words (47 trials). Results are summarized in Table 3. In longer words, the pattern of results seemed to fit the expectations: there was only a small difference between the identical and homophonous condition, but the allomorph condition appeared slower and was significantly slower than the baseline ($t = 2.17$,$p = 0.03$). However, the pairwise comparisons revealed only a marginally significant difference between the homophonous and allomorph condition ($p = 0.05$). There was no significant pairwise difference between the identical condition and the allomorph condition. In the group of shorter words, responses in the identical and the allomorph condition were slower than the baseline ($t = 2.58$,$p = 0.01$ for identical, $t = 2.94$,$p < 0.01$ for allomorph). In post-hoc analysis, there were no significant differences between conditions.

In trials with verb targets, there were only two conditions. Reaction times were 14 ms slower in the homophonous condition than in the identical condition. This difference approached statistical significance ($t = 1.71$,$p = 0.08$). Because the observed difference conflicted with the prediction, the analysis was repeated for shorter and longer words, with the expectation that the results for shorter words would fit the original prediction. In the 24 trials with 7- and 8-letter-long words, the responses were 8 ms slower in the homophonous condition, a nonsignificant difference ($t = 0.77$,$p = 0.44$). In the 12 6-letter trials, there was a significant 28 ms effect ($t = 2.06$,$p = 0.04$) with faster reactions in the identical condition.

Discussion

The predictions for Experiment 1 were only partially confirmed. No significant difference between the priming effects of homophonous suffixes was found, which was in line with the predictions. However, the reaction times in the identical condition were significantly slower than the baseline, while those in the homophone condition were very close to the baseline. The two conditions with the *-a* suffix in the primes may thus have differing priming effects, which was not expected. The allomorph condition resulted in the slowest reaction times, being significantly slower than both the baseline and the homophone condition.

The differences between the identical and allomorph condition might be due to differences in the progress of processing in prime words of different lengths. The subsequent analysis supported this view to a certain extent. The difference between the effects of identical and homophone primes was weaker in long words, which were presumably processed to a lesser extent. However, even here, the two critical conditions did not pattern in a completely identical manner and only the homophone condition showed a marginally significant advan-

Table 4: Top: overall reaction times and the condition effects in verbs. Bottom: reaction times and effects form Experiment 1, separately for long and short words. $^{**}p < 0.01$, $^{*}p < 0.05$, $\dagger\, p < 0.10$

	50 ms	150 ms
Verb 2pl. *-ete*	735	707
Genitive noun *-ete*	†14	**21

	50 ms	
Word length (letters)	6	7, 8
Verb 2pl. *-ete*	705	743
Genitive noun *-ete*	*28	8

tage over the allomorph condition. In longer words, there were no significant pairwise differences between the conditions, but the identical and allomorph conditions were significantly slower than the baseline, while the homophone condition was not.

The analysis of the verb component showed a marginally significant effect of condition, with homophonous targets showing a tendency to slower responses. The subsequent analyses for longer and shorter words suggested that the marginal effect could be attributed to short words, which showed significantly longer reactions in the homophone condition. Apparently, 50 ms is enough time for the word processing system to start accessing the function of a suffix at least in shorter words.

Some of the findings are surprising, especially the relative effects of the identical and homophone condition in nouns and verbs. The pattern in verbs was in line with intuition: if there is any difference between conditions, the homophone condition should be slower, since the suffix on the homophone primes only shares its form, but not its function with the target suffix. In shorter verbs, there was indeed a significant difference in this direction. However, the pattern in nouns appears to be opposite. There was a tendency in the identical condition towards slower reaction times than in the homophone condition. This was especially apparent in the group of shorter nouns, where the identical condition, but not the homophone condition, was significantly slower than the baseline. Possible reasons for this pattern are addressed in the general discussion below.

Experiment 2

Experiment 2 presented the same stimuli with longer SOA. Under these conditions, it was expected that the homophonous condition will elicit slower reaction times than the identical condition. If the function of the suffix is accessed within the chosen SOA (150 ms), the effect of the identical and allomorph suffix should be identical, or at least their difference should be smaller than in the homophonous condition.

Method

Design, procedure, participants Experiment 2 used the same design, stimuli and procedure as Experiment 1. The only difference was in the stimulus onset asynchrony. The primes were presented for 150 ms. Responses were collected from 38 students who volunteered or participated in exchange for course credit. None of the students participated in Experiment 1.

Results

The results are summarized in Tables 2, 3, and 4, along with the results from Experiment 1. In the noun component, the reaction times in all three experimental conditions were significantly slower than in the baseline condition (identical: $t = 2.57$, $p = 0.01$; homophone: $t = 3.93$, $p < 0.001$; allomorph: $t = 2.23$, $p = 0.03$). Pairwise post-hoc analysis revealed no significant differences between the individual levels. The direction of the differences was in line with the expectations, with the longest reaction times in the homophone condition, and the allomorph and identical condition eliciting similar responses. However, none of the pairwise differences between the experimental conditions were significant.

In order to examine the results more closely, the stimulus set was again split, and the groups of short and long words were analyzed. In the shorter words, there was a significant difference between the baseline and the homophone condition ($t = 2.41$, $p = 0.02$), as well as the allomorph condition ($t = 2.67$, $p = 0.01$). This would suggest an advantage for the stimuli primed with the identical suffix. However, post-hoc pairwise comparisons have not revealed any significant difference between the experimental conditions. Therefore, even though there seems to be an advantage for the identical condition, the prediction is not supported.

In the group of long words, the pattern of results is different. Compared to the baseline, the reaction times were significantly slower in the identical condition ($t = 2.42$, $p = 0.02$) and in the homophone condition ($t = 3.14$, $p < 0.01$). Pairwise comparisons revealed a significant difference between the allomorph and homophone condition, with homophone condition significantly slower than the allomorph condition ($z = 2.62$, $p = 0.04$).

In the verb targets, the reaction times in the homophone condition were significantly slower than in the identical condition ($t = 2.88$, $p < 0.01$). The results from the verb component are in line with the predictions.

Discussion

In Experiment 2, the predictions were again confirmed only partially. In the verb component, the homophone condition was slower than the identical condition, which is in line with the expectations. However, the expected differences in the more complex, noun component of the study have not materialized completely. Overall, there was a nonsignificant tendency for the reaction times to be longer in the homophone condition (20 ms effect against baseline) than in the identical or allomorph condition (13 and 12 ms effect, respectively).

This would be in line with the expectations. However, separate analyses for shorter and longer words complicated the picture. In the group of shorter words, more thorough processing of the primes is expected. The results should be in line with the predicted pattern. However, the homophone condition, predicted to be the slowest, has practically identical effects as the allomorph condition. These two conditions are significantly slower than the baseline. While this is not in line with the prediction, it is understandable under the assumption that the effects of orthography and function are about equally strong at 150 ms SOA. In the homophone condition, the response is inhibited by the difference in the morpheme function (accusative instead of a nominative marker). In the allomorph condition, the function is the same, but processing is inhibited by the difference in orthography. In any case, there was no significant pairwise difference between the identical condition and the two slower conditions, so the effects should be understood as a mere tendency.

In longer nouns, the pattern of results was more intriguing. Responses in the identical and homophone conditions were significantly slower than the baseline. Pairwise comparisons showed a significant advantage of the allomorph condition over the homophone condition. This appears to suggest that in these words, the function of the suffix is more influential than its orthographic form, since the condition with the different-function suffix is significantly slowed down. However, in such a case, the identical condition should be even faster than the allomorph condition. Another surprising aspect of the results is the fast response in the allomorph condition. The longer words are presumably processed to a lesser extent than the shorter words discussed above. Yet, the inhibiting effect of orthography against the baseline is present in the shorter, more completely processed words, and not in the longer words. This goes against the assumption that the orthographic form is accessed first and the function later. Moreover, it goes against other aspects of the present data. The allomorph condition was slower than the baseline both in Experiment 1, where the primes were presumably processed to a lesser extent, as well as in the short words in Experiment 2, where the processing of the primes progressed more than in the long words.

General discussion

The experiments examined the effects of morphological priming on word recognition. While the phenomenon has been well established with derivational morphemes, little research is available for inflectional morphemes. The results show that inflectional affixes can exert priming effects similar to those reported by Duñabeitia et al. (2008) and others for derivational affixes. However, the evidence is unequivocal only for the 2nd person plural verb suffixes at 150 ms SOA. For nominal suffixes, the result show a more complex pattern.

In verb targets in Experiment 2, the presentation of a noun prime with homophonous suffix inhibited word recognition compared to verb primes with identical suffix. This means that after 150 ms from the prime onset, the processing of the suffix moved beyond the level orthography, and words ending with homophonous suffixes inhibited the processing of target words. In Experiment 1, no such difference was predicted. It was expected that mere orthographic overlap between the prime and target suffix would initially affect the targets equally strongly as the repeated presentation of an identical suffix in the prime and target. However, it appears that in short words, the ending is recognized even within the 50 ms window, resulting in a morphological priming effect exceeding the effects of orthography.

The results from nouns require more detailed discussion. There was no significant difference between the two key conditions (identical and homophone) in Experiment 1, which was predicted. However, it was predicted that these two conditions would result in significantly faster responses than in the allomorph condition. This was true only for the homophone trials. Trials with identical suffix primes had longer reaction times than the homophone trials, and were not significantly different from the allomorph trials. This should not occur if the initial decomposition is blind to the function of the prime ending Moreover, the difference between the homophone and identical trials, though nonsignificant, goes in the unexpected direction and contradicts the findings from the verb component.

It is useful to summarize the results from the two key conditions based on the presumed amount of processing performed on the primes. On longer words with shorter SOA, i. e. after the least amount of processing, none of these conditions is faster than the baseline. In shorter words and short SOA, the identical condition is slower than the baseline. In longer words with 150 ms SOA, both identical and homophone conditions are slower than the baseline. Finally, with longer SOA and shorter words, only the homophone condition is slower than the baseline. This result is in line with the prediction that in the later stages of processing, the functional aspect of the affixes will play stronger role than their orthographic form. However, it is not clear why the primes with identical and homophone suffixes result in slower processing of long words in Experiment 2, and why identical suffixes inhibit processing of short word targets in Experiment 1.

One possible explanation is that morphological decomposition does not occur in frequent nominative forms. In this view, the processing system attempts morphological decomposition unless it can recognize the whole word form as a whole. If decomposition is attempted, the function morpheme is initially identified regardless of its function. If it is not attempted, there is nothing that would exert priming effect on the targets. If this view is correct, the accusative homophone primes in this experiment were decomposed. The *-a* suffix was initially not identified as accusative but activated all possible meanings, including nominative. For this reason, it facilitated the processing of the nominative target words. The nominative primes were not decomposed and thus could not exert the priming effects. This would explain the tendency

towards slower responses in the identical condition in Experiment 1, as well as the absence of the difference between identical and homophone primes in longer words in Experiment 2. In these longer words with 150 ms SOA, the homophone prefix presumably started to develop an inhibitory effect due to the functional difference between primes and targets. At the same time, the lack of priming due to the lack of nominative prime decomposition still inhibited processing after the identical primes.

This view may seem paradoxical. If nominatives are not decomposed, why should the decomposed *-a* affix from the accusative primes temporarily activate the nominative interpretation? The possibility must exist that a low-frequency word or a novel word will be analyzed as nominative. For this reason, separating the *-a* suffix activates the nominative interpretation, even though nominatives are not regularly decomposed. Another question that arises is why nominative targets should be facilitated if they are not decomposed. But it is not necessary to assume that facilitation of target processing operates on the suffix. The activation of nominative *-a* suffix on the prime may activate the whole corresponding declensional class of nouns (paradigm "žena"). There is independent evidence that declensional class of nouns is represented in an abstract manner (Bordag & Pechmann, 2009). This way, the target nouns could be primed even if not morphologically decomposed.

The reason why nominatives would not be decomposed lies in the fact that they function as the base and default form. Nominatives are considered the citation form of nouns, and they are the most frequent case form (Jelínek, Bečka, & Těšitelová, 1961). It has been proposed that only low-frequency words undergo morphological decomposition (Baayen, Dijkstra, & Schreuder, 1997; Baayen & Schreuder, 1999). Even though there is evidence that all suffixes, including pseudo-suffixes, are decomposed, the decomposition of nominatives may be slower than direct retrieval. In that case, nominatives would not be decomposed.

This proposed explanation might explain many aspects of the results reported here. Some aspects remain unexplained, especially the fast responses in the allomorph condition on long words in Experiment 2. In any case, the processes of morphological decomposition of inflectional suffixes deserve closer scrutiny. In particular, further research needs to test whether nominative words undergo morphological decomposition.

To summarize, findings from Experiment 1 suggest that the purely orthographic, function-blind stage of morphological decomposition may be over in less than 50 ms, at least in shorter words. At the same time, results from the noun targets in both experiments suggest the possibility that nominative forms do not undergo morphological decomposition.

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