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Morphological processing in nominalizations

A priming study on Dutch

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A major debate in psycholinguistics concerns the representation of morphological structure in the mental lexicon. We report the results of an auditory primed lexical decision experiment in which we tested whether verbs prime their nominalizations in Dutch. We find morphological priming effects with regular nominalizations (*schorsen* 'suspend' → *schorsing* 'suspension') as well as with irregular nominalizations (*schieten* 'shoot' → *schot* 'shot'). On this basis, we claim that, despite the lack of phonological identity between stem and derivation in the case of irregular nominalizations, the morphological relation between the two forms, suffices to evoke a priming effect. However, an alternative explanation, according to which the semantic relation in combination with the phonological overlap accounts for the priming effect, cannot be excluded.

Keywords: morphological processing, nominalizations, stem allomorphy, priming

1. Introduction

A long-standing debate concerns the role of morphological structure and whether listeners use morphological decomposition in regular and irregular nominalizations during spoken word recognition. While some claim that there is no role for morphology during the processing of 'complex' words, i.e. that all words are stored as whole-word forms (e.g. Manelis & Tharp 1977; Norris & McQueen 2008), others argue that listeners decompose complex words into their morphological constituents during word recognition (e.g. Fruchter & Marantz 2015; Taft 2004; Taft & Forster 1975). Yet others argue for an intermediate position, in which a distinction is made between regular cases, which are presumably dealt with

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by decomposition, and irregular cases, which rely on storage (e.g. Bertram et al. 2000; Frauenfelder & Schreuder 1992; Pinker & Ullman 2002). Furthermore, there are theories of morphology that store the complex forms with their morphological structure (e.g. Bybee 1995, Booij 2010).

Much of the empirical foundation of this debate rests on behavioral experimentation, more in particular, on priming experiments (for an overview, see Crepaldi et al. 2010). However, there is no consensus on whether complex words are processed as morphologically complex or are lexically listed. In an attempt to find new ways to examine the issue, behavioral experimentation has been complemented by neuropsychological approaches (e.g. Labbé Grunberg 2020; Morris & Stockall 2012; Stockall & Marantz 2006). In this paper, we contribute to the ongoing discussion by investigating regular and irregular nominalizations in Dutch and report the results of an auditory priming experiment. Sticking to a purely behavioral priming method, we extend the empirical testing ground in two ways. First, our empirical domain is formed by nominalizations rather than the past tense, exchanging inflectional for derivational morphology. Second, while previous studies have mostly focused on the visual processing of complex words, we examine spoken-word processing (following a recent line of work; see Wilder et al. 2019 for discussion).

2. Nominalization in Dutch

Dutch verbs can be nominalized in different ways. First, there are several nominalizing suffixes, as illustrated in (1):

(1)	**verb**	**nominalization**
	beheers 'control'	*beheers-ing* 'control'
	crem-eer 'cremate'	*crem-atie* 'cremation'
	zaag 'saw'	*zaag-sel* 'sawdust'

Some of these suffixes are productive, whereas others cannot be extended to any new stems. The suffix *-ing* is highly productive: it can be found after numerous verbs, and adding *-ing* to a nonce stem makes the stem a verb. The suffix *-atie* is only used to nominalize verbs ending in *-eer*. Here, the nominalizer directly follows the root, rather than the verbal stem. The suffix *-sel* is unproductive, occurring only with a small class of verbs. Most theories of morphology assume that nominalizations with productive suffixes indeed are morphologically complex, while theories disagree regarding the unproductive cases, which are sometimes argued to be stored as whole forms. However, what these suffixes have in common, is that they do not alter the phonological form of the verb they attach to. Therefore, we refer to these nominalizations as morpho-phonologically *regular*.

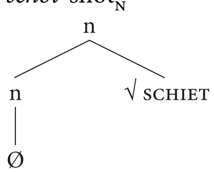
A second way in which nominalizations are formed in Dutch, is through an *irregular* word formation process, as illustrated in (2).

(2)

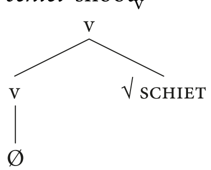
verb	nominalization
drink 'drink'	*drank* 'drink'
schiet 'shoot'	*schot* 'shot'
stink 'smell'	*stank* 'stench'
bied 'offer, bid'	*bod* 'offer, bid'

Some theories (so-called Root-and-Category theories of morphology, e.g. Borer 2017; Halle & Marantz 1993; Lowenstamm 2015) claim that irregular nominalizations are complex as well, in the sense that we can break them down in a 'root' and a nominalizing element, which has no overt spell-out, as illustrated in (3a) for *schot* 'shot$_{N}$'. The same root also underlies the verb *schieten* 'shoot$_{V}$', which has the structure in (3b).

(3) a. *schot* 'shot$_{N}$'



b. *schiet* 'shoot$_{V}$'



The structure in (3a) illustrates that it is not the vowel-change that 'spells out' the nominalizer. Rather, the nominalizer has no overt realization, and it is a mere 'readjustment' of the stem in the context of this nominalizer that is responsible for the lowering of the stem-vowel.

In sum, we may say that Dutch nominalizations form a cline that goes from regular productive suffixes, via less productive and even unproductive suffixes, to irregular cases that have no (overt) suffix, only showing a change in the stem vowel. From the perspective of Root-and-Category morphology, all these cases involve some form of (de)composition, whereas other theories of morphology may locate the division between storage and computation at different points on this cline. As indicated above, there are theories that allow storage of forms *with* their morphological structure. It is not always clear what this would mean in the case of allomorphy of the type under investigation (with (3) as an example). For example, Booij (2010) acknowledges that allomorphy does not "impede the recognition of relatedness between words with a common constituent" (ib: 254). However, it is not clear what the common constituent in cases as (3) would be for theories relying on storage of overt phonological forms.

In the present study, we use behavioral data obtained by priming as a window into the morphological representations that listeners cognitively entertain. We use verbs as primes and nominalizations as targets, testing four types of nominalizations: irregular nominalizations (e.g. *schieten* 'shoot$_V$' → *schot* 'shot$_N$'), and regular nominalizations with the three different suffixes discussed above, viz. *-ing* (e.g. *schorsen* 'suspend' → *schorsing* 'suspension'), *-atie* (e.g. *isoleren* 'isolate' → *isolatie* 'isolation') and *-sel* (e.g. *raden* 'guess' → *raadsel* 'puzzle'). The idea behind morphological priming is that a prime like *schorsen* activates the root √SCHORS, which remains active and is therefore above its resting level of activation when the target *schorsing* is presented. If the target contains the same root √SCHORS, response times to the target are predicted to be faster in the primed case, relative to an unrelated baseline (Stockall & Marantz 2006: 90). Consequently, under a Root-and-Category theory of morphology that assumes a structure as in (3), we expect to find priming effects even in irregular cases. However, under theories that do not claim that the two forms in (3) share an underlying abstract morphological core, we expect to find a lack of priming for irregular cases, and additional differences based on productivity in the regular cases.

3. An auditory primed lexical decision experiment

In order to test whether morphological relatedness facilitates word recognition in nominalizations, we ran an auditory-auditory primed continuous lexical decision experiment that used prime-target pairs consisting of a verb and its nominalization. The regular and irregular nominalizations form two sub-parts of the experiment and will be discussed as such.

3.1 Methods

3.1.1 *Materials*

The irregular nominalization targets are paired with four prime conditions in a within-target design (see Table 1). The Morphological (M) prime condition consists of the infinitive of the verb the nominalization is derived from. All irregular targets show a vowel alternation with respect to their related verb stem (e.g. *schiet* /sxit/ 'shoot$_V$' ~ *schot* /sxɔt/ 'shot$_N$'). Nominalizations identical to the past tense form are excluded (e.g. *spring* 'jump' ~ *sprong* 'jumped/jump$_N$'), as well as irregular nominalizations with affixes such as *ge-* (***ge**wicht* 'weight'), *-en* (*leug**en*** 'lie$_N$'), and *-t* (*jach**t*** 'hunt$_N$'). (Pseudo-)prefixed nominalizations are included only if the prefix is part of the verb as well, and if the prefix is inseparable (as in e.g. ***be**drog* 'betrayal'). Finally, all nominalizations are relatively semantically transparent with respect to their related verb.

To make sure that any priming effect obtained for the morphological condition is due to morphological relatedness between target and prime, and not to semantic or phonological relatedness, we controlled for these factors by adding two more conditions: a Phonological (Ph) and a Semantic (S) condition. In the Ph-condition, we include words that show a similarly large phonological overlap with the target as the morphological prime does (e.g. *schatten* /sxɑtən/ for *schieten* /sxitən/, to the target *schot* /sxɔt/). This means that, apart from the inflectional ending, Ph-primes and targets typically differ in one phoneme only, or two phonemes at most. In the S-condition, we include primes that form strong semantic associates of the target (e.g. *pistool* 'pistol' → *schot* 'shot$_N$'). These primes were selected using the Dutch Association Lexicon (De Deyne et al. 2013), the largest available network of word associations in Dutch. Finally, we include an Unrelated (Unr) prime condition, in which primes are unrelated in meaning, morphology, and phonology to their targets. This condition functions as a baseline in the sense that any difference between this condition and the other conditions is by definition a priming effect. All conditions are matched as much as possible for frequency (see Table 1).[1]

Table 1. Example items and mean frequencies (Lg10CD from SUBTLEX-NL; Keuleers et al. 2010) for the irregular nominalizations. Standard deviations are given in parentheses

	Morphological (M) prime	**Phonological (Ph) prime**	**Semantic (S) prime**	**Unrelated (Unr) prime**	**Target**
Example	*schieten* 'shoot'	*schatten* 'estimate'	*pistool* 'pistol'	*lezen* 'read'	*schot* 'shot'
Frequency	2.81 (0.66)	2.17 (0.71)	2.36 (0.58)	2.82 (0.68)	2.49 (0.64)

While our main interest lies in the irregular nominalizations, we also include regular nominalization targets with the suffixes *-ing*, *-atie*, and *-sel*, by means of a

1. As pointed out to us by a reviewer, the nominalizations included differ in how verb-like their semantics still is; compare e.g. *schorsing* 'suspension' (which is an event) to *raadsel* 'puzzle'. We did not control for this semantic factor here, nor in the irregular cases.

baseline (Table 2). Primes are formed by the infinitival forms of the verbs, which are pair-wise matched on frequency and number of syllables to unrelated primes.

Table 2. Example items and mean frequencies (Lg10CD from SUBTLEX-NL; Keuleers et al. 2010) for the regular nominalizations (with *-ing*, *-sel*, or *-atie*). Standard deviations are given in parentheses

	Morphological (M) prime	**Unrelated (Unr) prime**	**Target**
Example (*-ing*)	*schorsen* 'suspend'	*aaien* 'stroke$_V$'	*schorsing* 'suspension'
Frequency	2.50 (0.72)	2.49 (0.72)	2.20 (0.36)
Example (*-atie*)	*isoleren* 'isolate'	*verzwijgen* 'conceal'	*isolatie* 'isolation'
Frequency	1.99 (0.56)	1.99 (0.57)	1.77 (0.73)
Example (*-sel*)	*raden* 'guess$_V$'	*zwemmen* 'swim'	*raadsel* 'puzzle'
Frequency	2.30 (0.70)	2.30 (0.71)	1.34 (0.92)

In total, 24 irregular targets were included, resulting in 96 irregular prime-target pairs, and 12 regular targets per suffix type, resulting in 72 regular prime-target pairs. We ensured that each participant saw each target only once, by rotating critical items according to a Latin Square design. We included 150 filler pairs to prevent awareness of what the experiment was about, and 210 pseudo-words for the purpose of the lexical decision task.

3.1.2 *Apparatus*

The stimuli were recorded by an adult female native speaker of Dutch in a sound attenuated booth, using a high-quality microphone. Sound files were segmented in Praat and normalized to a peak amplitude of 70 dB SPL. The task was implemented in PsychoPy2 (Peirce 2007). Stimuli were presented auditorily to the participants through headphones.

3.1.3 *Procedure*

A continuous primed lexical decision task was used, in which participants made lexical decisions to all items. The task had a random Inter-Stimulus Interval between 600–800 ms. Stimulus presentation was randomized for each participant. The experiment consisted of four blocks with a self-administered break after each block, and a practice trial of 10 items at the beginning of the experiment. Participants were instructed that they would hear existing and non-existing Dutch words, and that they had to make a lexical decision to each word as fast and as accurately as possible. Responses of 'word' and 'non-word' were recorded from keyboard button presses on a laptop. The stimuli were presented auditorily to the participants through headphones. The experiment lasted on average for 15.3 minutes per participant.

3.1.4 *Participants*

Participants were 35 native speakers of Dutch (mean 27.05; sd 13.80; 23 female), who reported having no reading, hearing of other language disorders. Participants were recruited through the social network of the first author, and most participants were students in higher education (HBO/WO). Participants were paid 5 euros for their participation, and provided written informed consent prior to the start of the experiment. Ethical approval for the study was provided by the Ethics Committee Faculty of Humanities at the University of Amsterdam, with protocol identification number 2019-FGW_PSYL-11341.

3.2 Results

3.2.1 *Analyses*

Responses to targets were coded for response type (word/non-word) and response time (RT; measured in ms from the onset of the sound file). The overall minimum accuracy was 83.57%. Inaccurate trials (inaccurate responses to prime or target) were discarded (removing 187 observations out of 2100 trials). Following procedures in Baayen and Milin (2010), we combine minimal a-priori data trimming with model criticism. Targets with outlier RTs (< 100 ms and > 2000 ms) were excluded as well as the targets for which the prime had an outlier RT, excluding 45 observations. The RT data were log-transformed, and removal of outliers was done for 8 individual subjects and 13 individual items for which Shapiro-Wilk's tests for normality showed non-Normal distributions, excluding 35 further observations.

We analyzed effects on log-transformed RT with linear mixed-effects models, using the lme4 package (Bates et al. 2015) in R. We fit separate models for the irregular and regular targets. The model for irregulars includes a fixed effect of CONDITION (M, Ph, S, Unr); the model for regulars includes an interaction between CONDITION (M, Unr) and SUFFIX TYPE (*-ing, -atie, -sel*). Additional fixed effects in both models were TRIAL NUMBER, ISI, TARGET FREQUENCY, PRIME FREQUENCY, TARGET DURATION, PRIME RT, and PARTICIPANT'S AGE, and both models include random intercepts for SUBJECTS and TARGETS. CONDITION is treatment coded with the Unrelated condition as the reference level and is releveled for multiple comparisons with the irregular targets. SUFFIX TYPE is also treatment coded and releveled for multiple comparisons. TRIAL NUMBER, ISI, TARGET FREQUENCY, PRIME FREQUENCY, DURATION, PRIME RT, and AGE are z-scored. Residuals exceeding than 2.5 standard deviations from the mean were trimmed following Baayen and Milin (2010), excluding 21 observations for the regular targets (out of 1126) and 12 observations for the irregular targets (out of 707). P-values are determined using the package lmerTest (Kuznetsova et al. 2016); significant p-values are reported at $p<0.05$.

3.2.2 *Results irregular nominalizations*

We first present the results of the *irregular* nominalizations, as presented in Figure 1 and 2, and Table 3. The model indicates significant differences with the Unrelated condition for the M-condition ($\beta=-0.127$, $p<0.001$), the Ph-condition ($\beta=-0.041$, $p=0.007$), and the S-condition ($\beta=-0.054$, $p<0.001$). In other words, we find significant priming effects in all conditions. When releveling the reference level of CONDITION to M, we find significant differences between RTs in the M and Ph-conditions ($\beta=0.086$, $p<0.001$) and the M and S-conditions ($\beta=0.073$, $p<0.001$), with significantly shorter RTs in the M-condition.

In addition, the model indicates significant effects for TRIAL NUMBER ($\beta=-0.014$, $p=0.005$), TARGET DURATION ($\beta=0.057$, $p<0.001$), PRIME RT ($\beta=0.037$, $p<0.001$), and AGE ($\beta=0.035$, $p=0.002$). No significant effects were found for ISI ($p=0.305$), TARGET FREQUENCY ($p=0.716$), PRIME FREQUENCY ($p=0.187$).

Table 3. Response times (RTs) to irregular nominalizations. Standard deviations are given in parentheses

	M	Ph	S	Unr
RT (ms)	908.75 (168.55)	983.81 (166.68)	974.02 (173.33)	1033.54 (188.22)
Priming (ms)	124.80	49.73	59.52	–

3.2.3 *Results regular nominalizations*

We now turn to the regular nominalizations, as presented in Figure 3 and 4, and Table 4. The model indicates significant differences between the Unrelated condition and the M-condition for nominalizations with *-ing* ($\beta=-0.096$, $p<0.001$), with *-atie* ($\beta=-0.080$, $p<0.001$), and with *-sel* ($\beta=-0.111$, $p<0.001$). Moreover, the priming effects (Unrelated vs. M) for the different suffix types do not differ from each other: the effect for *-ing* does not differ from the effects for *-atie* ($p=0.363$) and *-sel* ($p=0.407$), and the effect for *-sel* does not differ from the effect for *-atie* ($p=0.081$).

In addition, and as with the regular targets, the model indicates a significant effect for TRIAL NUMBER ($\beta=-0.033$, $p<0.001$), TARGET DURATION ($\beta=0.106$, $p<0.001$), and PRIME RT ($\beta=0.043$, $p<0.001$). In contrast to the regular targets, no

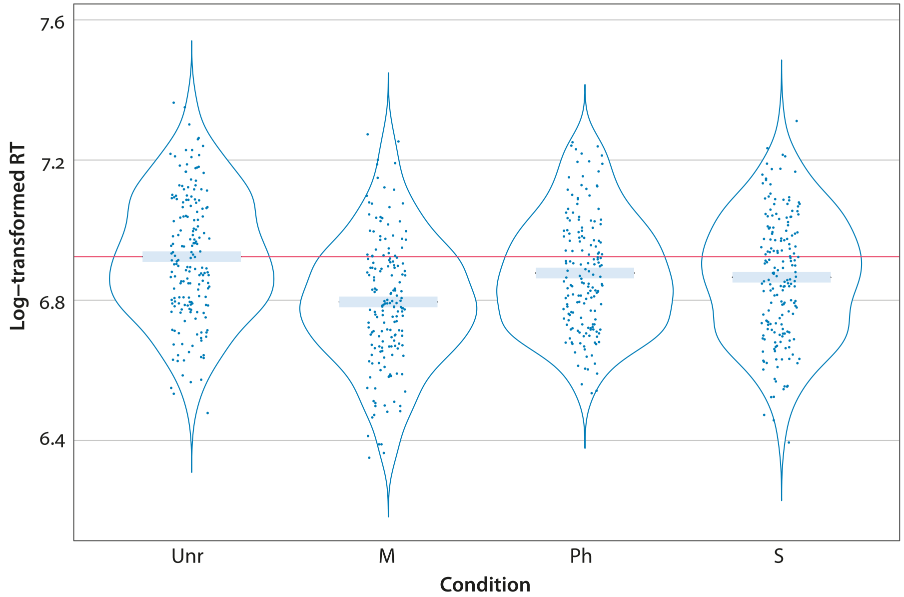


Figure 1. Violin plots showing the distribution of the log-transformed RTs to *irregular* targets. The blue bars represent the means; the red line represents the mean in the Unrelated condition

significant effect for AGE was found ($p=0.096$). The effects for ISI ($p=0.734$), TARGET FREQUENCY ($p=0.118$), and PRIME FREQUENCY ($p=0.347$) also did not reach significance.

Table 4. Response times (RTs) to regular nominalizations suffixed with *-ing*, *-atie*, and *-sel*, preceded by Morphological (M) and Unrelated (Unr) prime conditions. Standard deviations are given in parentheses

	-ing	*-atie*	*-sel*
RT M (ms)	939.38 (162.70)	1047.76 (204.92)	922.36 (163.70)
RT Unrelated (ms)	1025.83 (185.74)	1134.84 (202.04)	1028.72 (179.12)
Priming (ms)	86.46	87.08	106.36

4. Discussion of the results

For the irregular nominalizations, we find significant priming effects in all conditions. Yet, the effect in the M-condition (e.g. *schieten* 'shoot$_V$' → *schot* 'shot$_N$'; 124.80 ms) is significantly greater than in the Ph-condition (*schatten* 'estimate$_V$' →

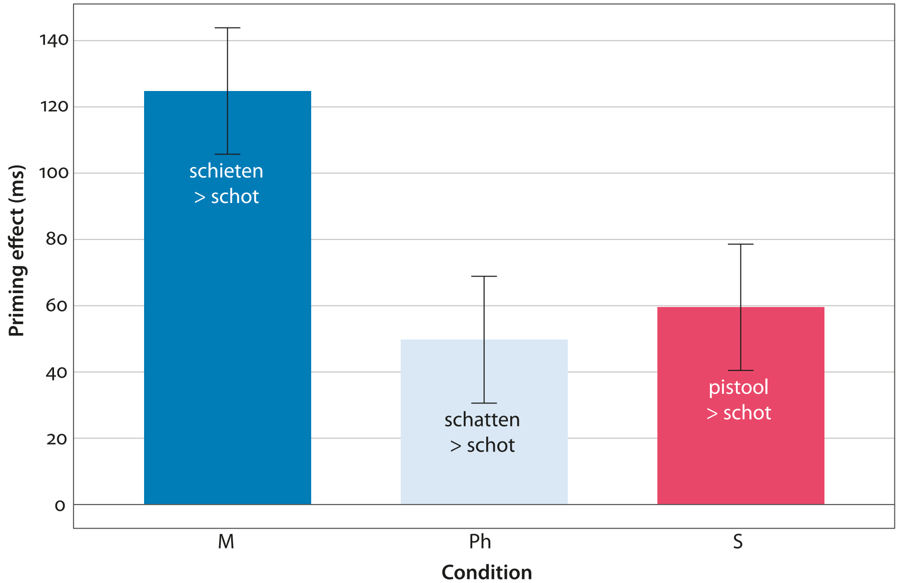


Figure 2. Priming effects (in ms) for *irregular* targets. Error bars represent ±1 standard error of the sampling distribution of differences

schot 'shot$_N$'; 49.73 ms) and S-condition (*pistool* 'pistol' → *schot* 'shot$_N$'; 59.52 ms), and numerically greater than the combined effects in the Ph and S-conditions. These results show that irregular nominalizations can be primed by the verb they are derived from. The significant difference with the Ph and S-conditions strongly suggests that the priming effect in the M-condition is distinct from phonological and semantic effects.

The results suggest that there is a stage in the processing of *schot* 'shot$_N$' at which the same morphological root is activated as is part of the verb *schieten* 'shoot$_V$', and that morphology constitutes an abstract level of processing that is independent of phonological and semantic relatedness. However, an alternative explanation that we cannot fully rule out, is one in which the morphological effect is the result of some non-additive effect of formal and meaning overlap, in the sense that there is an additional 'boost' for words that are both semantically and phonologically related (see e.g. Seidenberg & Gonnerman 2000 for a proposal along these lines).

Regarding the regular nominalizations, we also found significant priming effects for all suffix types: for *-ing* (*schorsen* 'suspend' → *schorsing* 'suspension', 86.46 ms), for *-atie* (e.g. *isoleren* 'isolate' → *isolatie* 'isolation', 87.08 ms) and for *-sel* (e.g. *raden* 'guess' → *raadsel* 'puzzle', 106.36 ms). The longer RTs for the *-atie* nominalizations (1047.76 ms) compared to the *-ing* (939.38 ms) and *-sel* (922.36 ms)

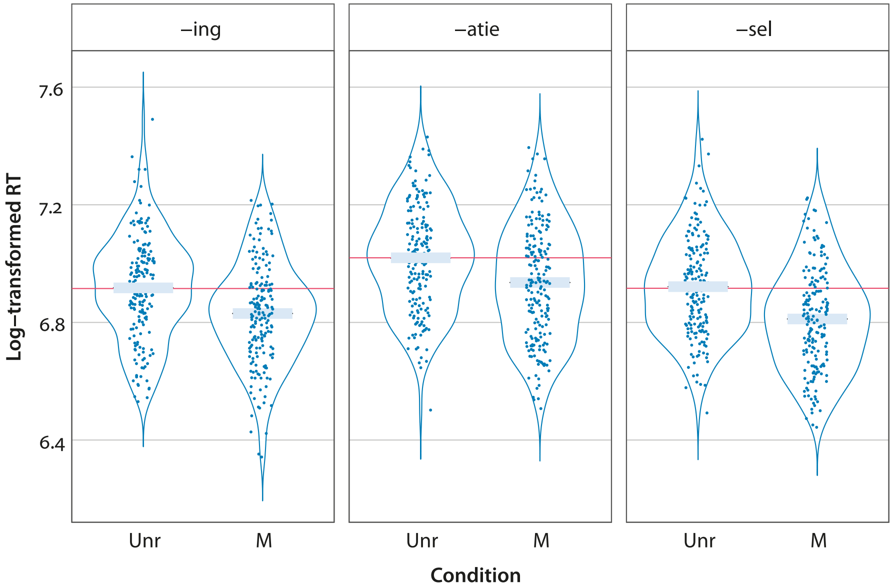


Figure 3. Violin plots showing the distribution of the log-transformed RTs to *regular* targets. The blue bars represent the means; the red lines represent the means in the Unrelated conditions

nominalizations is likely due to the longer target duration in the *-atie* nominalizations, which had an average duration of 1093 ms compared to 798 ms for *-ing* and 844 ms for *-sel*. Numerically, the priming effect for nominalizations with *-sel* seems greater than the other regular nominalizations, but these differences do not reach significance.

We picked the different suffixes based on how productive they were: both *-ing* and *-atie* are relatively productive, while *-sel* only occurs with a small set of verbs. This difference in productivity did not lead to significant differences in the priming effects, and neither did the difference in frequency between the surface forms of the nominalizations (*-ing*: 2.20; *-atie*: 1.77; *-sel*: 1.34) as also indicated by the lack of a significant effect for target frequency in the model. This result is incompatible with theories proposing storage of high frequency and unproductive forms (Baayen 1992; Stemberger & MacWhinney 1988).

5. Conclusion

As has been pointed out by Marantz (2013a), the notion 'morpheme' has become somewhat slippery in present-day morphological theory. Since morphologists

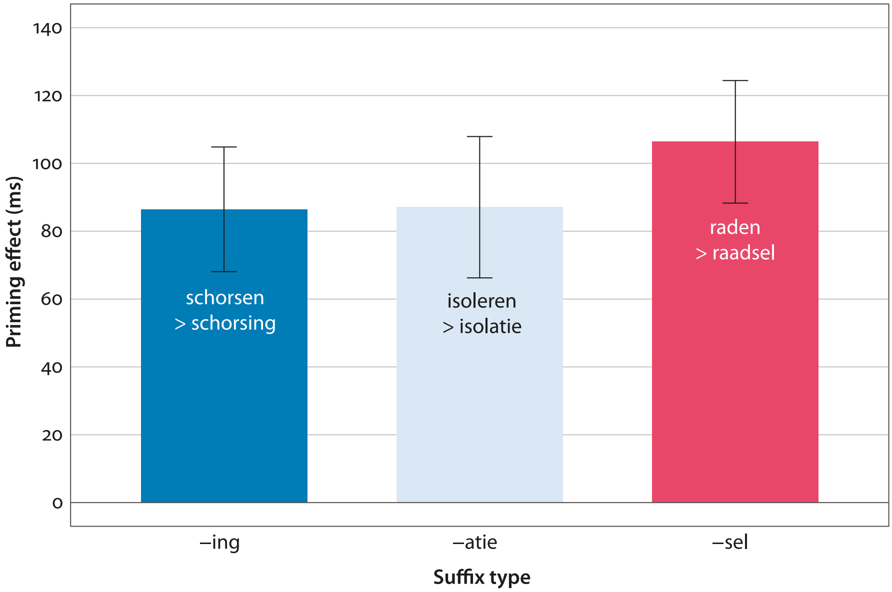


Figure 4. Priming effects (in ms) for *regular* targets. Error bars represent ±1 standard error of the sampling distribution of differences

such as Anderson (1992), and Beard (1995) showed that morphosyntactic content and phonological realization are two separate things, this 'separation' has received broad acceptance among theoretical morphologists. This entails that a morpheme cannot be equated with a fixed phonological representation that always encodes the same semantics. Rather, it is an abstract unit, which, at least for its form, but to some extent also for its meaning (see e.g. Marantz 2013b), depends on the syntactic, and phonological context in which it occurs.

The experiment reported in this paper shows that Dutch verbal stems prime irregular nominalizations in a similar way as verbal stems prime regular nominalizations. On this basis, we claim that, despite the lack of phonological identity between stem and derivation in the case of irregular nominalizations, the morphological relation between the two forms, that is, their shared abstract morphological root, suffices to evoke a priming effect. However, as noted above, an alternative explanation, according to which the semantic relation in combination with the phonological overlap accounts for the priming effect, cannot be excluded. Ways to rule out this latter explanation involve testing whether morphological priming effects are still obtained in cases where the semantic relation between the two forms is distant (e.g. *zuigen* 'to suck'; *zog* 'mother's milk', along the lines of Creemers et al. 2020), or in cases with a complete lack of phonological overlap, as with suppletive forms. We leave this for future research.

Acknowledgements

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