

V. The natural perceptual salience of affixes is not incompatible with a central view of morphological processing

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1. INTRODUCTION

The Strong Morphonotactic Hypothesis (Dressler & Dziubalska-Kolaczyk 2006) assumes that phonotactics helps in the decomposition of words into morphemes. Accordingly, sequences occurring over a morpheme boundary (e.g. *mords*, *mordent*, *mordre* /mɔʁ/ /mɔʁd/ /mɔʁdɛ/) correspond to a prototypical morphonotactic sequence that should be processed faster and more accurately than phonotactic sequences (e.g. *ordre* /ɔʁdɛ/).

While this issue is usually explored within studies on typical and atypical first language acquisition, a recent study carried out by Korecky-Kröll et al. (2014) tested this hypothesis with German-speaking adults. One experiment using a letter search task (i.e. find a letter like, for example, *T* at different positions – initial, medial, final – in a visual word like *Taube* ‘dove’, *dank-te* ‘thanked’ and *pack-t* ‘(s/he) packs’) investigated whether sublexical letter sequences were found faster when the target sequence was separated from the word stem by a morphological boundary (e.g. *pack-t*) than when it was a part of a morphological root (e.g. *Lift* ‘lift’). The results showed that the presence of a morpheme boundary led to shorter reaction times (RTs) and fewer errors, whatever the target cluster position in the word. The authors concluded that phonotactics helps in the decomposition of words into morphemes without, however, explicitly considering that it is a direct consequence of a morphological decomposition mechanism taking place during lexical access.

More recently, Beyersmann et al. (2014) examined the morpho-orthographic hypothesis according to which all complex forms are segmented into morphemes during lexical access. The prefixed and suffixed let-

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ter strings they manipulated comprised real stems and affixes but never formed an existing word in French (e.g. *propoint*, *filmure*). They used a letter search task in which adult French speakers had to decide whether the target letter was present or absent in a string of letters (e.g. ‘R’ in *propoint* or *filmure*). The results revealed that the letter search took longer in suffixes compared with non-suffix endings but not for prefixes compared with non-prefix beginnings. Moreover, performance was not affected by letter cluster frequency. The difference in processing suffixes relative to non-suffixes was interpreted as reflecting a chunking/affix stripping mechanism (cf. Taft & Forster’s serial hypothesis 1975) that operates on functional units such as suffixes during lexical access. Furthermore, the authors interpreted the absence of effects for the prefixed non-words (i.e. no significant difference between pre-fixed and non-prefixed non-words) in terms of the different semantic and syntactic functions of prefixes relative to suffixes.

Giraudo and Grainger (2003) also found an asymmetry in the processing of prefixed vs. suffixed words in a series of masked priming experiments conducted with French complex words. More precisely, they found morphological masked priming effects, but only for prefixed words (i.e. *enjeu* ‘stake’ primed *envol* ‘flight’, while *ennui* ‘boredom’, a pseudo-complex in which *en-* is not a prefix and *lapin* ‘rabbit’, an unrelated word, did not induce any priming effect), suggesting that only prefix series are activated at the very early stages of visual word recognition. The authors interpreted this asymmetrical processing in terms of the different linguistic functions these two types of affixes imply, in particular the fact that prefixes usually carry more transparent semantic information than suffixes, whose function is much more related to syntax. Accordingly, morphological priming effects using affixed words would rely on the semantic relationships in prime-target pairs – prefix priming effects being clearly obtained. This result constitutes a challenge for decompositional models situating morphological effects at a sublexical level that should be insensitive to semantics. Moreover, the conclusions reached by Beyersmann et al. (2014) are not only contradictory to what Giraudo and Grainger (2003) found about affix processing in French but they are also incompatible with what Korecky-Kröll et al. (2014) found concerning the target cluster position, which did not interact with RTs in their experiment. Therefore, the conclusion about the kind of cognitive processes underlying affixed word analysis is not clear, while the interpretation of the effects obtained with a letter search task has to be re-examined.

As a consequence, and because Beyersmann et al. (2014) tested non-words instead of existing words, meaning that they did not control the

morphonotactic characteristics of their material, it is worth carrying out a new experiment using words and controlled materials in order to tease apart the morphonotactic effects from the positional effects in word recognition. Working on non-words presents the advantage of creating the materials very easily, especially when formal aspects have to be controlled. However, working on the morphological issue, the manipulation of non-words, even if they are morphologically complex, restricts the conclusions derived from the results. First, the morphological structure of a given word actually corresponds to both the form and meaning information, and second, this word is embedded in a network formed by its morphological family and series. Therefore, the manipulation of non-words suppresses the two morphological dimensions of complex words, their syntagmatic and paradigmatic structure (see Blevins 2014 for discussion).

Finally, it is worth highlighting that, according to us, the letter search task does not permit examination of lexical access per se but rather morphological salience. Recently, Giraudo and Dal Maso (2016) discussed the issue of morphological processing through the notion of morphological salience – defined as the relative role of the word and its parts – and its implications for theories and models of morphological processing. The issue of the relative prominence of the whole word and its morphological components has indeed been overshadowed by the fact that psycholinguistic research has progressively focused on purely formal and surface features of words, drawing researchers' attention away from what morphology really is, systematic mappings between form and meaning. While we do not deny that formal features can play a role in word processing, an account of the general mechanisms of lexical access also needs to consider the perceptual and functional salience of lexical and morphological items. Consequently, if we acknowledge the sensitivity to the word's morphological structure, we claim that it corresponds to secondary and derivative units of description/analysis.

In the present research, a letter search task was carried out using French words; the main comparison is between the words that include the target letter after a morphonotactic boundary (e.g. *vivre* 'to live') and those with a purely phonotactic one (e.g. *centre* 'centre'). The hypothesis is that morphonotactic segmentation will be facilitated because of a double salience conveyed in the boundaries, as it is not only phonological but also morphological. Position effects will also be explored, as we compare the initial (position 1) vs. the final position (position 2) of letter targets. The results are presented with both a categorical analysis (comparing the different conditions) and a linear mixed-effects model.

2. METHODOLOGY

2.1. PARTICIPANTS

Thirty participants were recruited at the University of Toulouse, all native French speakers. The age range spanned from 18 to 30 years old (average 23); 7 were male and 23 were female. All participants were right-handed with normal or corrected to normal vision.

2.2. ITEMS

Sixty French word forms (the same inflectional form) were used as targets; those used for the critical condition can be segmented morphotactically, while for the 3 other control conditions the syllabic segmentation was purely phonotactic (phonology and morphology did not correspond). All words included a combination of the letters 'RE', half of the time at the beginning of the word and half of the time at the end. Four conditions were created in order to counterbalance the position (initial-final), the boundary type (morphological and phonological or only phonological) of the bigram to be searched, and the part of speech status (verb or noun in singular and infinitive) of the word (see Table 1 for stimuli characteristics).

15 verbs morphonotactic (**MP verb_RE/P2**): verbs that had the letters 'RE' in a final position (after a consonant at the end of the word), and corresponded to a morphological and phonological boundary. For example, *vivre* 'to live' contains *viv-* as a morphological base (stem) and *-re* as a suffix (the infinitive mark).

15 nouns phono final (**P noun_RE/P2**): nouns that ended with 'RE', but the phonotactic boundary did not correspond to the morphological one. For example, in *centre* 'centre', *-re* is not a suffix and *cent-* is not a stem.

15 verbs phono initial (**P verb_RE/P1**): verbs that started with 'RE', but the phonotactic boundary did not correspond to the morphological one. For example, in *refuse* 'refuse' *re-* is not a prefix and *-fuse* is not a stem.

15 nouns phono initial (**P noun_RE/P1**): nouns that started with 'RE', but the phonotactic boundary did not correspond to the morphological one. For example, in *religion* 'religion' *re-* is not a prefix and *-ligion* is not a stem.

In order to perform the task, 60 filler words (30 nouns and 30 verbs) matched in length and frequency with the target words, but not having 'RE' clusters in their spelling, were used. All word frequencies were taken from the *Lexique* database (New et al. 2001).

Table 1. Stimuli controlled for frequency and length

Condition	Fx ³	Length
Morphono (verb_P2) <i>vivre</i>	38.04	6.13
Phono (noun_P2) <i>centre</i>	32.04	6.20
Phono (verb_P1) <i>refuse</i>	30.12	6.33
Phono (verb_P1) <i>religion</i>	15.89	6.20

2.3. PROCEDURE

Participants were seated 50 cm from the computer screen and asked to perform a ‘letter search task’. They were instructed to respond as rapidly and accurately as possible to whether the cluster of letters ‘RE’ was present or not in the word to be displayed on the screen. Participants responded ‘yes’ by pressing one of two response buttons with the forefinger of their right hand and ‘no’ by pressing the other response button with the forefinger of the left hand.

The DMDX software (Forster & Forster 2003) was used. Each trial consisted of the following sequence of stimuli: the letters to be searched (RE) presented in uppercase (for 700 ms), followed by a fixation mark (1000 ms), a French word in lowercase (50 ms), which, in turn, was replaced by a mask (#####) that remained on the screen until the participant responded (for a maximum of 1500 ms). After 10 practice trials, participants received the 120 experimental trials in one block in a randomized order (see Figure 1 for a trial example).

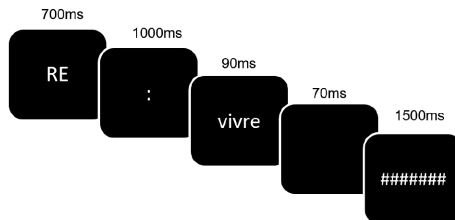


Figure 1. Trial example for the letters search task (RE)

³ Frequency (Fx) calculated in frequency per million from the Lexique corpus database (New et al. 2001). Length corresponds to the average number of letters.

3. RESULTS 1

For the statistical analyses, filler words (with no RE clusters) are not considered. Accuracy across all participants was above 80% but no significant differences were found (see Table 2 for accuracy and reaction time means). For the reaction time (RT), trials considered ‘errors’ were not taken into account (6% of the data), and a trimming procedure was used: excluding responses under 300 ms (1.6% of the data) and 2.5 SDs above or below the mean response time of each participant (2.89% of the data). For the RTs (see Figure 2 for RT means), an ANOVA was conducted using participants (F1) as a random factor, treating the boundary type as a within-participant factor (repeated measures).

Table 2. Accuracy (in error rates) and reaction times (in milliseconds) means

RT	MP(verb_P2)	P(noun_P2)	P(noun_P1)	P(verb_P1)
Mean	606.20	664.38	573.55	607.18
SD	97.20	128.86	102.10	110.63
ACC	MP(verb_P2)	P(noun_P2)	P(noun_P1)	P(verb_P1)
Mean	4.67	7.56	5.11	5.33
SD	6.35	8.53	5.45	5.37

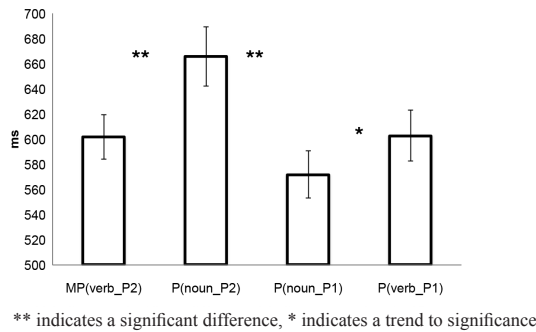


Figure 2. Reaction time results (ms) with standard error bars (SE) of the mean for each of the different conditions

A main effect of position was found, and planned comparisons found that the only significant difference among the four conditions was that the response times for the ‘MP’ condition were significantly faster $F(3,59) = 8.72$ $p < .01$ than those obtained for the ‘P’ with RE in the first position (beginning).

Focusing on the comparison between the two conditions where the target letters were at the beginning of the word and the only difference was the boundary type, the MP condition produced a facilitation effect (over the P one). To disentangle these findings and explore whether the effects are due to the fact that these conditions differ in grammatical category (part of speech), a comparison between these variables was undertaken, but it showed no significant difference.

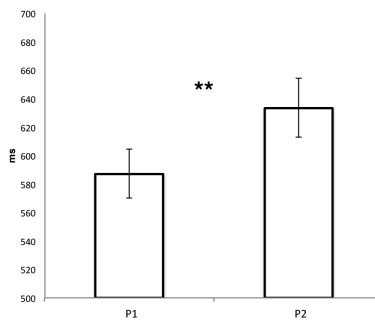
3.1. POSITION

An ANOVA revealed a significant difference between the initial and final position: $F(1,59) = 9.92$, $p < .01$, indicating that participants' responses are faster (by 76.33ms) when the target letters ('RE') are in an initial position, taking together conditions P(noun_P1) and P(verb_P1), versus when they are in a final one, MP(verb_P2) and P(noun_P2).

The average RT for the compiled values obtained for the conditions with 'RE' at the end or at the beginning of the word are shown in Table 3 and Figure 3.

Table 3. Mean average RT (and standard deviation, SD) of position (initial vs. final) in milliseconds

POSITION	RT (SD)
Initial (P1)	587.3 (133.66)
Final (P2)	633.63 (160.66)
Net Effect (P1-P2)	76.33



** indicates a significant difference ($p < .05$)

Figure 3. Mean average RT of position (initial vs. final) in milliseconds with SE bars

Looking only at the ‘position’ effect, it can be argued that ‘RE’ is identified faster (regardless of whether the boundary is morpho-phonological or purely phonological) when it is at the beginning of the word; this may be due to the fact that we follow a left-to-right reading direction. Nevertheless, in order to disentangle the findings, when comparing morphonotactic to merely phonotactic boundaries, there is a significant effect for the morphonotactic condition. If position is the only factor, manipulation or variable considered, then ‘RE’ is always found faster when at the beginning of the word but, within this position, ‘RE’ is found significantly faster when the boundary is morphonotactic. This is probably due to the dual information conveyed, which enhanced the morphological salience, aiding the analysis of the word into its constituents and facilitating identification of the target letters.

3.2. PART OF SPEECH (GRAMMATICAL CATEGORY)

The average RT for the compiled values obtained for the conditions containing ‘RE’ in verbs or nouns are shown in Table 4. An ANOVA revealed no significant difference between them $F(1,59) = 1.93$, $p = .17$, indicating that even if participants’ responses are slower (by 16.54 ms) when the target letters (‘RE’) are in a verb (condition MP_verbRE and P_RE_verb) than when they are in a noun (P_nounRe and P_RE_noun), this numerical difference is not statistically significant. The average RT for the compiled values obtained for the conditions containing ‘RE’ in verbs or nouns are shown in Table 4 and Figure 4.

Table 4. Mean average RT per part of speech
(verb vs. noun) in milliseconds

PART OF SPEECH	RT (SD)
Verb	602.19 (136.51)
Noun	618.73 (161.22)
Net Effect (V-N)	-16.54

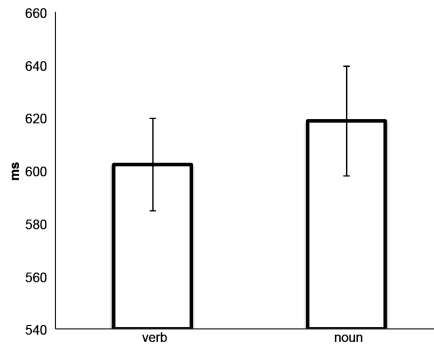


Figure 4. Mean average RT per part of speech (verb vs. noun) in milliseconds with SE bars

3.3 MORPHONOTACTIC VS. PHONOTACTIC

In the comparison of average RTs between the two conditions where the target letters were at the beginning of the word (P1) and the only difference was the boundary type, a facilitation effect was found for the morphonotactic boundary type (compared to the purely phonotactic). Figure 5 shows the average RT and significant difference between the type of boundary (MP or purely phonotactic).

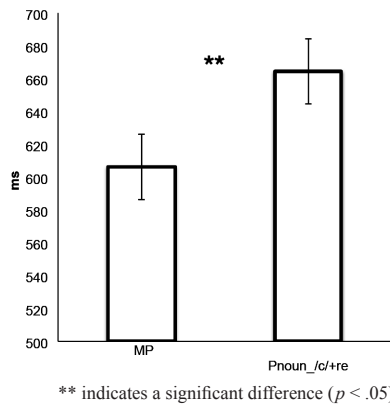


Figure 5. Reaction time results in milliseconds with SE bars of the mean for morphonotactic vs. phonotactic P2 conditions

4. RESULTS 2

It is also interesting to examine the possible correlation between the RT and a set of variables related to all formal (surface) aspects of the words, such as the length in terms of characters, the number of syllables and the orthographic neighbourhood. The reaction times (log) of correct responses were also analysed using a linear mixed-effects model. The fixed factor predictors included are the following:

a) condition (MP verb_RE/P2, P noun_RE/P2, P verb_RE/P1, P noun_RE/P1)

b) ortho_neigh (number of orthographic neighbours)

c) nbsyll (number of syllables),

d) nbletters (number of letters or word length)

e) TP_ORT (orthographic transitions probability)

f) FrWaC_freq (the log frequency of the form in FrWAC corpus, Baroni et al. 2009).

Table 5. Linear mixed-effects results of the reaction time data

Groups	Name	Variance	SD			
Random	effects:					
word	(Intercept)	0.0005587	0.02364			
participant	(Intercept)	0.0317204	0.1781			
Residual	0.0582263	0.2413				
Predictor	Estimate	Std.	Error	df	t	Pr(> t)
Fixed effects:	effects:					
(Intercept)	6.263813	0.068259	49.21	91.766	<2e-16	***
Condition P(noun_RE)	0.065327	0.025253	8.35	2.587	0.0312	*
Condition P(RE_noun)	-0.055352	0.031062	13.17	-1.782	0.0978	.
Condition P(RE_verb)	-0.015291	0.038177	18.54	-0.401	0.6933	
ortho_neigh	-0.001171	0.003072	48.53	-0.381	0.7047	
nbsyll	-0.009288	0.022931	50.92	-0.405	0.6871	
nbletters	0.019177	0.010635	49.74	1.803	0.0774	.
TP_ORT	-0.160263	0.180087	46.15	-0.89	0.3781	
log(FrWaC_freq)	-0.00961	0.0038	20.54	-2.529	0.0197	*

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Participants and items were included as random effects. In particular, the TP_ORT variable reports the transitional probability of bigrams corresponding to the last letter of the target word (e.g. <v> in viV-re and the next subsequent letter of the letters to be searched (e.g. viVRe, that is the conditioned probability that an <r> follows a letter <v>). Table 5 shows the results obtained from the linear mixed-effects model and Figure 6 shows the significance of standardized fixed effects.

A significant effect of boundary type is found, showing that participants identify the letters within words that included morphological and phonotactic boundaries faster than in words with a purely phonotactic one (in P2). The intercept (morphonological condition: MP verb_RE/P2, our ‘base case’) was significant, meaning that the RTs (for finding the letter ‘RE’ in this condition) seem to reflect a facilitation effect, while the phonological condition (P noun_RE/P2) shows an inhibitory effect (longer RTs are needed to respond). In both of these conditions, the target letters are in the final position of the word (P2).

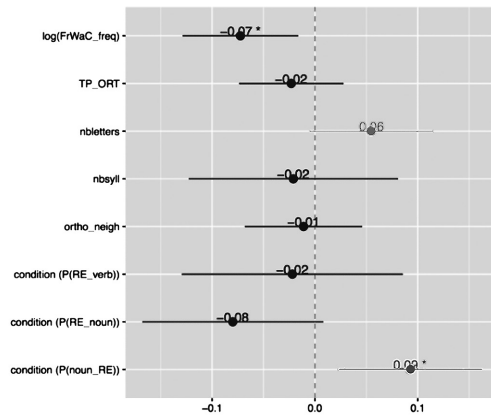


Figure 6. Standardized fixed effects showing that frequency, length and condition are significant

The model predictors are the following (see Figure 7):

- Condition: Reaction times (log) during the letter search task for each of the boundary-type conditions (1) MP verb_RE/P2, (2) P noun_RE/P2, (3) P verb_RE/P1 and (4) P noun_RE/P1.
- Frequency (FrWac_freq): The higher the frequency of the word form (same inflectional form), the lower the reaction times responses associated with it.
- Length (nbletters): Contrary to frequency (and as expected), as the length of the word increases, the RT also increases.

- d) Number of Syllables (nbsyll): Follows the trend for the length of the word, but the effect is not significant.
- e) Orthographic Neighbours (ortho_neigh): The more orthographic neighbours a word form has, the trend for the reaction times is to decrease, but this is not significant.
- f) Transition Probability (TP_OR_T): No significant effect was found.

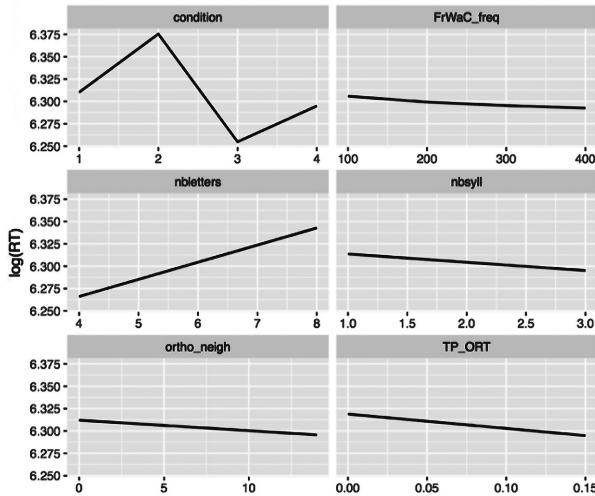


Figure 7. Marginal effects of model predictors

1. CONCLUSION

The Strong Morphonotactic Hypothesis (Dressler & Dziubalska-Kołaczyk 2006) was tested following the letter search task paradigm using words in French with morphonotactic and phonotactic boundaries with different positions for the targets across the materials. The target could be either at the beginning of the word (position 1) or at the end (position 2). Globally, the results showed that prototypical morphonotactic sequences were processed faster than phonotactic sequences, suggesting that phonotactics help us perceive the internal word structure in terms of morphological construction by enhancing their morphological salience. The presented results revealed that this was the case for position 2 (but not position 1): letter search times were longer when the target letters were embedded in a phonotactic condition compared to a morphonotactic one.

Our findings also provide indirect evidence for the left-to-right bias in word-recognition processing asymmetry across word beginnings and

ends, and we assume that the mechanisms underlying printed word recognition are shaped by the physical constraints imposed by the reading direction (Giraudo & Grainger 2003). Responses were indeed significantly longer for the items that had the target letters in the second position (P2) compared to those in the first position (P1).

A significant effect of frequency was also obtained, showing that the more frequent a word is, the faster the reaction times are, while all other variables (like orthographic neighbours, transition probability and grammatical category) were found to be not statistically significant. According to our view of morphological processing (Giraudo & Voga 2014; Voga & Giraudo 2017), morphology plays a central role in the cognitive system at two levels: at a perceptive/surface level (when the morphological structure is salient, as is the case for morphonotactic words), and at a central level (where paradigmatic relationships organize the word representations coded in the mental lexicon). We claim that finding sensitivity to morphology and effects of abilities is compatible with a paradigmatic/construction view of morphology (e.g. Booij 2010). On the one hand, morphological salience can speed up lexical access in adult word comprehension and help to develop the morphological awareness of those learning to read. Morphological awareness refers to children's "conscious awareness of the morphemic structure of words and their ability to reflect on and manipulate that structure" (Carlisle 1995: 194). Accordingly, it contributes to reading ability (e.g. Brittain 1970; Carlisle 1995; Deacon & Kirby 2004; Mahony, Singson & Mann 2000; Nagy, Berninger & Abbott 2006; Nunes & Bryant 2006; Kirby et al. 2012). Consequently, morphemes can provide cues for meaning, spelling and pronunciation (e.g. Carlisle 2003). On the other hand, construction representations link morphologically related words at a central level, and the presence or absence of connections is determined by the degree of semantic/functional relationships between the word forms according to their shared morpheme (base or affix). A fundamental assumption of this view is that construction representations are created/emerge and are stabilized in long-term memory according to an ecological rule that imposes family and series clustering as an organizational principle of the mental lexicon. To conclude, the claim is that the mental lexicon is constructed according to multiple dimensions: the perceptive salience of the word's morphological structure (enhanced by morphonotactics) and its formal-semantic relationships with the other coded words, in other words, its syntagmatic and paradigmatic dimensions.

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