Teasing apart syntactic category *vs.* argument structure information in deverbal word formation: A comparative psycholinguistic study

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Deverbal word formation is subject to two distinct types of constraints, those concerning the syntactic category of the base (categorial constraints) and those relating to the thematic properties of the verb (thematic constraints). For instance, *-able* suffixation involves a transitive verb with argument structure <Agent<Theme>>, as in *to train* > *trainable*. Violation of these constraints results in the creation of pseudo-words with categorial (e.g. *riverable*) or thematic violations (e.g. *arrivable*). The study discusses psycholinguistic experiments involving these types of deverbal pseudo-words, in Greek and English, two languages with morphologically distinct properties. Greek has a rich derivational system with a variety of deverbal formations, which follow strong constraints, in the sense that most suffixes that participate in deverbal word formation lack the polysemy that allows them to attach to other-than-verbal bases. English, on the other hand, demonstrates an equally rich derivational system, but it differs in two crucial ways: (a) there is significant affix homophony (e.g. *-er* is a nominalizer if attached to verbal stems, or forms the comparative if attached to adjectives), (b) it is extremely permissive in allowing zero-derived verbs (*to fax*). In an off-line and two on-line lexical decision tasks we investigated whether categorial and thematic constraints are treated in the same way by speakers of both languages. Results showed that speakers of both languages differentiated between pseudo-words that violate these two types of constraints both when it comes to acceptance rates and processing time. Taking together results from both languages, we make claims about the structured mental representation of deverbal derivatives and the fact that their various properties can be accessed via distinct operations and at distinct points of time. Implications for the psycholinguistic theory of lexical access and the morphological theory of word formation are also discussed.[*]

[*] The present paper relies on some of the same data reported in Manouilidou (2007), which focused on the investigation of thematic constraints in deverbal word formation in Greek. The Greek data reported here are the same but their

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1. Theoretical background

1.1. Approaches to word formation

The aim of the present paper is to investigate the ways in which different types of grammatical information are relevant in licensing deverbal word formation (derivational affixation of a verbal stem, e.g. *teach* > *teacher*). We focus on the role of the syntactic category and the argument structure specifications of verbal stems, and investigate how these two kinds of information are used by speakers processing novel affixed words in two morphologically distinct languages: Greek and English. We present the results of a series of experiments in which speakers of these languages were asked to judge the well-formedness of novel words like *softable* or *redance*, which violate either lexical category or argument structure restrictions on affixation.

Such restrictions can be very easily described in terms of rules or constraints on affixation: "*-able* can only attach to a verb stem", "*re-* requires a verbal stem with an internal argument", etc. The precise details of how to implement these restrictions depend, of course, on the specific theory of morphology and syntax one adopts. Lexicalist theories of word formation (Bauer 2001, Plag 1999, 2003, Ralli 2005) postulate the existence of interaction constraints which result from the relation of morphology to other components of grammar. These are constraints imposed by systems external to morphology (i.e. phonological, syntactic, and semantic) but which nonetheless constrain morphological operations (compounding, inflection, and derivation) in the lexicon. These constraints are considered to be universal, seemingly applying to every type of derivation at the moment of initial word formation (e.g. Ralli 2005). For instance, phonologically conditioned allomorphs illustrate constraints on the collocation of morphological elements. That is, the /ɪz/ allomorph of the English plural results from the phonotactic impossibility of clusters of stridents in English. The function of these general constraints does not preclude the existence of other constraints specific to certain derivational operations, such as deverbal word formation, which is the operation under investigation in the present paper.

analysis and interpretation is new, taking into account not only new statistical methodology and electronic corpora for frequency (that were not available till recently) but also new advances in theoretical and psycholinguistic theory. We are grateful to two anonymous reviewers and Phaedra Royle for insightful comments and suggestions. An earlier version of this paper was presented at New Territories in Word Formation that took place in Sofia, Bulgaria. We are grateful to the audience for their comments.

Bauer (2001: 126) makes a further distinction between strong and weak constraints. A strong constraint describes a process in which an affix attaches only to a particular type of base, such as the suffix *-ness* in English, which attaches only to adjectives (e.g. *happi-ness, white-ness*). Strong constraints are not violable. A weak constraint, by contrast, is one that expresses a preference or tendency, such as the fact that the English *-er* prefers verbal agentive bases (e.g. *teacher*), but can also attach to nonagentive verbs (e.g. *hearer*) and nouns (e.g. *villager*). In contrast, the Greek suffix *-tis* (an equivalent of *-er*) strictly attaches to agentive verbs, and is thus subject to a strong constraint in Bauer's terms. Apart from the issue of the rigorousness of general constraints within a specific language, there is also the issue of relative rigorousness of morphological constraints in different languages. The same constraint can be weak or strong depending on the language it is applied in, e.g. the agentivity constraint of *-er*/*-tis* in English and Greek respectively.

Models of morphology in which all word structure building occurs in the syntax and the phonological form of words is determined by post-syntactic spell-out processes which realize particular syntactic structures (Borer 1994, 1998, 2003, 2005; Embick and Marantz 2008; Halle and Marantz 1993, 1994; Harley 1995; Harley and Noyer 1999; Starke 2009, inter alia) implement such restrictions in terms of the possible pronunciation of a given structure. For instance, in their discussion of the ill-formedness of **gloriousity* (a case Aronoff 1976 analyses as involving word-word blocking), Embick and Marantz (2008) argue that the vocabulary item *-ness* should be analyzed as the default exponent of the functional little *n* head which attaches to roots to make nominals, while the vocabulary item *-ity*, on the other hand, is specified as only being possible when *n* is adjoined to a finite set of listed roots (including √ATROC and √CURIOUS), and when *n* is attached to an adjectival head *a* that is itself realized as *-able* or *-al*. Since √GLORY is not on the list of roots *-ity* co-occurs with, and since *-ous* is not on the list of realizations of *a* that *-ity* can co-occur with, the default realization of *n* kicks in, and [[√GLORY *n*] *a*] is pronounced as *gloriousness*, not 'glorio(u)sity'. Rather than distinguishing between s t r o n g and w e a k constraints on which roots or stems a particular affix can attach to, constructivist theories like Distributed Morphology posit more or less specified contexts for insertion of particular vocabulary items, such that English *-er* can be inserted in a wider set of contexts than Greek *-tis*.

Interestingly, despite very significant differences between lexicalist and constructivist approaches to morphological complexity, for the purposes of the current investigation, both types of theory propose that we learn and represent information about which affixes can combine with

roots and stems as properties of the affixes themselves (Aronoff 1976, Embick & Marantz 2008), rather than as properties of lexical roots or derived stems, and thus both models predict that speakers should be easily able to apply their knowledge about these restrictions to novel combinations of affixes and existing stems, or even to combinations of affixes with novel or pseudo stems. What concerns us in the current paper, then, is not so much adjudicating between these competing models of how, when and where in the grammar word formation occurs, but rather in examining whether the speed and accuracy with which speakers access and make use of word formation restrictions varies as a function of the kind of restriction, or the general restrictiveness of the particular language when it comes to word-formation processes.

The specific goal of the present research is to investigate the status of general and specific constraints in deverbal word formation by examining the processing mechanisms of pseudo-words (henceforth Pseudo-Ws) which violate these constraints. We compare Greek and English, which have importantly distinct morphological properties in order to explore the validity of these constraints cross-linguistically.

1.2. Deverbal word formation in English and in Greek

Deverbal word formation involves the creation of a lexical item which includes both a verbal stem (either a root or a derived verbal stem) and an affix. For this lexical item to be well-formed, the affix in question must, obviously, be able to attach to verb stems. Thus, a minimum requirement for a derived form to be categorized as deverbal is to be based on a verbal stem. In Bauer's system, this is a general and strong constraint since it determines the whole morphological operation. Deverbal word formation is also subject to a specific type of constraint which we will be referring to as thematic. Thematic constraints originate from argument structure properties that both the verbal stem and the suffix carry. For instance, *-simos* '-able' suffixation in Greek involves a transitive verb with the argument structure <Agent<Theme>>. The suffix binds the internal theme argument and externalizes it (Lieber 2004; Melloni 2012). When this is not possible, the derived form is ungrammatical, as shown in the contrast between (1a) and (1b)

(1)	a.	*ekpedévo* 'to train' <Ag <Th>>	→	*ekpedéfsimos* 'trainable' <Th<(Ag)>>
	b.	*tréxo* 'to run' <Ag>	→	**trék-simos* 'runable'

Similarly, the suffix *-tis* '*-er*' binds the external agent argument of the base verb, saturating it in the derived word (2a). Therefore, the addi-

tion of *-tis* to a verb which lacks an external agent argument results in an ungrammatical formation, as shown in (2b).

(2) a. *kolymbó* 'to swim' <Ag> → *kolymvitís* 'swimmer'
b. *ksexnó* 'to forget' <Undergoer> → **ksexastís* 'forgeter'

Finally, two more suffixes that are relevant for the present study and participate in deverbal word formation are *-tós* and *-tikós*, which create adjectives from verbal bases. Deverbal adjectives with the suffix *-tós* indicate that the modified noun can either be subject to the event or state described by the base verb, as in (3a), or that the modified noun is the theme of the event or state described by the verb, as in (3b). The same suffix also assigns a permanent and stable characteristic to the modified noun, as in (3c).

(3) a. *spázo* > *spastós* 'break > breakable'
b. *agapó* > *agapitós* 'love > lovable'
c. *plektós* 'knit', *skistós* 'split', *sfragistós* 'sealed', etc.

In terms of thematic constraints, the *-tós* derivatives do not inherit the thematic properties of the base verb to the fullest. The most important consequence of this is that *-tós* lacks the agent argument. That is, while *-tós* requires a verb with argument structure <Ag<Th>>, the derived words with *-tos* denote the state that corresponds to the result of the verbal activity bypassing some aspects of the verb meaning (Markantonatou *et al.* 1996; Manouilidou 2006). For example, by using the word *spastós* 'breakable', the speaker focuses on a property of the modified noun and not on the fact that this noun can be broken or was broken. As for the suffix *-tikós,* it indicates that the modified nouns are appropriate for the activity denoted by the base verb, e.g. *apagorévo* > *apagoref-tikós* 'prohibit > prohibitive', *voithó* > *voithi-tikós* 'to help > helpful', *epivarýno* > *epivaryn-tikós,* 'aggravate > aggravating'. In terms of thematic constraints, *-tikós* strictly chooses verbs with the argument structure <Ag<Th>>.

Similar operations take place in English as well, even though the rigorousness of the constraints on word formation is not always as strong. For instance, the suffix *-en* binds the internal Theme argument of a transitive verb (4a) to create past participles and its attachment to unergative verbs (with <Ag> argument structures) results in ungrammatical formations (4b).

(4) a. *written*, *beaten*, *eaten*
b. **blushen*, **laughen*, **runnen*

Constraints do not only apply to suffixation, but to prefixation as well, such as the interesting case of *re-* which requires an internal, affected argument (see Horn 1980, Levin & Rappaport 1986, Weschler 1989, Keyser & Roeper 1992, Williams 2006, Marantz 2007). Explanations for why this restriction holds vary according to the analysis, but there is clear consensus that *re-* attaches to unaccusatives (with <Th> argument structures) and transitive accomplishment verbs, but not unergatives or transitive achievements, activities or stative verbs. Thus, the derived verbs in (5a) are grammatical while those in (5b) are ungrammatical.

(5) a. *reopen*, *repaint*, *rebuild*, *reclose*
b. **resmile*, **reboast*, **reshiver*, **resnort*, **relaugh*

However, in English, many affixes are either idiosyncratically restricted to attach to a particular set of roots and stems, as is the case with *-ous*, discussed above, or else the same phonological form can express a range of different syntactic and semantic features and attach to a range of lexical bases. One of the most famous cases of this kind of homophony is *un-* prefixation (Andrews 1986, Bowerman 1982, Clark *et al*. 1995, Funk 1988, Horn 2002, Kemmerer & Wright 2002, Marchand 1969, Pollatsek *et al.* 2010, Pylkkänen, Olivieri & Smart 2009, Sawada 1995). The *un-* that attaches to adjectives has simple negation semantics, and can attach to any adjective, but the *un-* that attaches to verbs has restitutive semantics and generally requires its stem to describe an accomplishment (Dowty 1979) (i.e. a complex event consisting of a process that leads up to a change of state) as examples in (6) show. This homophony/ambiguity issue extends to non-deverbal suffixes as well, such as the suffix *-ish* which attaches equally to nouns and to adjectives as the examples in (7) show (although again with different semantic interpretations). The fact that what at least appears to be the same affix can attach to bases of more than one syntactic category is a property that specifically characterizes the English morphological system and will be discussed below in more detail in comparison to Greek.

(6) a. un- + Adj, *unhappy*, *unwilling*, *unafraid*
b. un- + $\text{Verb}_{[\text{ACCOMP}]}$, *unlock*, *untie*, *undo*
c. un- + $\text{Verb}_{[\text{-ACCOMP}]}$[1], **unthink*, **unlove*, **undance*

(7) a. Adj + -ish, *longish*, *tallish*, *greenish*
b. Noun + -ish, *feverish*, *slavish*, *waifish*

As is evident above, the crucial difference between the two languages under investigation is the fact that in Greek, affixes are very strict in selecting a specific syntactic category for their base. With respect to the distinction outlined in the introduction between strong and weak constraints, Greek suffixes that participate in deverbal word formation (creating either nouns or adjectives) tend to follow strong constraints regarding both categorial (syntactic category) and argument (thematic) structure properties of the base. In other words, most suffixes (with very few exceptions) only participate in deverbal word formation and lack the polysemy that would allow them to attach to a variety of bases and form lexical items belonging to different categories. Thus, suffixes like *-tis, -tós, -simos,* and *-tikós* which are relevant for the present study strictly attach to verbal bases.

English, on the other hand, allows a series of morphological operations which are not possible in Greek. For instance, zero-derived verbs, such as *to fax, to table, to chair* are very common in English, but impossible in Greek. Moreover, as discussed above, English allows the same affixal form to attach to bases with multiple syntactic categories. An alternative way of approaching this phenomenon, which also constitutes a difference compared to Greek, is that English roots could be more easily described as being underspecified when it comes to syntactic category (Halle & Marantz 1994, Marantz 1997). Unlike Greek, where roots are explicitly morphologically marked as verbal, nominal, etc., English roots appear to only provide the type of meaning that could potentially be classified as event, state, and entity. For instance, roots that modify entities canonically merge with a little *n* nominal head (creating nouns); state modifiers canonically merge with a little *a* adjectival head (creating adjectives), and event modifiers canonically merge with little *v*, but these are merely tendencies, and many roots can merge with more than one type of category-determining head (see Marantz 1997, 2013, Arad 2003 and Levinson 2007, 2010 for discussion). If this is the case, there must be flexibility in the ways in which root meanings combine with various structures and suffixes, implicating polysemy of roots and/or semantic type shifting in which a canonical entity modifier is shifted to event modifier (Marantz 2013: 159). Given that flexibility exists, it is not clear whether and to what extent it expands to argument structure constraints such as the ones outlined in the previous section. The experiments outlined below investigate these issues.

2. Processing syntactic category and argument structure information in derived words

A large number of studies have been carried out to investigate the

possible effects of morphological structure on lexical access of complex items, with the most fundamental question being whether they are accessed through decomposition into their constituents (e.g. *un-deniable*) or as wholes (e.g. *undeniable*). Until recently, conflicting research findings had led researchers to fall into two opposite camps,[2] those supporting strict decomposition during lexical access (starting with Taft & Forster 1975) and those suggesting that lexical access occurs via a stored representation of the whole word (starting with Butterworth 1983). Despite the existence of occasional counter-examples (Crepaldi *et al.* 2010; Giraudo & Grainger 2001; Giraudo & Voga 2013)[3] these debates have been quite conclusively resolved thanks to converging evidence from behavioral and neuroimaging experiments investigating how we process pseudo-derived words like *apartment* and *brother,* which can be exhaustively parsed into an existing stem and affix (*broth + -er*), but which are not in any way morpho-semantically complex, or related to the putative stems in meaning (a *brother* is not 'one who broths'). Behavioral lexical decision experiments using a masked priming paradigm in which participants have less than 40ms of exposure to a complex or pseudo-complex prime (*teacher*, *brother*) followed by a 'stem' (*teach*, *broth*) find significant priming effects for both prime types, and no difference between the magnitude of these effects, but find no priming at all for pairs like *brothel~broth* which share the same degree of form overlap, but are not parsable as a stem + affix (see Rastle & Davis 2008 for a review of the more than 20 studies finding this pattern of results across a range of languages). Meanwhile, magnetoencephalography (MEG) experiments investigating the evoked neural activity associated with genuinely complex (*teacher*, *excitement*) and pseudo-complex (*brother*, *apartment*) words in a simple single word reading paradigm find significantly increased activation peaking around 150-180ms after stimulus onset, and originating in the left anterior fusiform gyrus (the Visual Word Form Area, Cohen *et al*. 2000) for both real and pseudo-complex words, but not for matched unsegmentable monomorphemic words (Zweig & Pylkkänen 2008, Lewis *et al.* 2011). Similar experiments investigating regularly and irregularly inflected words (*walked, sold*) using the masked priming paradigm in behavioral (Marslen-Wilson *et al*. 1993, Meunier & Marslen-Wilson 2000) and neuroimaging (Royle *et al.* 2012, Morris & Stockall 2012, Fruchter *et al.* 2013) studies also find compelling evidence for early, automatic, obligatory morphological decomposition on the basis of orthographic form, prior to access to semantic features.

This body of research forms a solid basis to suggest that the human processor actively looks for morphemes when confronted with a lexical

item, supporting a model of lexical access in which morphological constituents are rapidly and automatically detected on the basis of their visual form. The evidence is quite clear that access to the lexical semantics of the stem is a later process, occurring after initial form-based decomposition, given that decomposition is often made without the contribution of semantics, as postulated from the body of cited research. The obvious question that arises is what features or properties of stems and affixes *are* available at early stages. Two recent neuroimaging studies (Dikker *et al*. 2010, Whiting *et al*. 2013) both find evidence for early access to lexical category information.

Specifically, using MEG, Dikker *et al*. (2010) found that an unexpected word category (e.g. 'the recently princess…') elicited enhanced activity in visual cortex as early as 120ms after exposure. The authors interpret this activity as a function of the compatibility of a word's form with the form properties associated with a predicted word category, stressing the extremely early onset of syntactic category effects in language processing. Dikker *et al.* (2010) show that the human processor not only decomposes words automatically but it can also evaluate syntactic category signaling morphology very quickly in a highly predictive context.

Whiting *et al*. (2013) also provide evidence for rapid and automatic processing of syntactic category in spoken word recognition of affixed (derived and inflected) and pseudo-affixed words (nouns and verbs) and Pseudo-Ws. The authors acquired concurrent MEG-EEG data at the onset of each type e.g. *bakes-baker-bacon, beaks-beaker-beacon, *bokes-*boker-*bokon,* using an oddball paradigm designed to evoke a Mismatch Negativity Response (Näätänen *et al*. 1997). Results showed that the presence of morphological complexity (affixed words vs. pseudo-affixed words) resulted in increased left-lateral activity while affixed verbs showed greater left-lateralization in the inferior frontal gyrus compared to affixed nouns (e.g. *bakes* vs. *beaks*), in both cases within 150-250ms after the onset of the stimuli. This latter result demonstrates that early neural activity is modulated not only by morphological structure but also by the lexical category of the stem.

These results, however, rely either on highly predictive sentence contexts which trigger very strong top-down expectations about lexical category and functional morphemes (Dikker *et al*. 2010, see also van Berkum *et al*. 2005 for a similar experiment in Dutch)[4] or rely on a paradigm (the Mismatch Negativity technique) in which there is only a single unique item in each experimental condition (repeated hundreds of times). Thus, the evidence from these studies for rapid, form-based access to lexical category information relevant to morphological well-formedness is suggestive, but not conclusive.

In contrast, the research presented here builds on Manouilidou (2006), who carried out a series of studies investigating deverbal nominals and deverbal Pseudo-Ws in Greek by using the lexical decision paradigm. The goal was to investigate whether the processing of argument structure information (or thematic features) constitutes a necessary step in lexical processing for complex and pseudo-complex words. Results showed that thematic features appear to increase the processing load only for a subset of derivatives, namely only for those with a strong eventive character according to Alexiadou (2001) (e.g. *plýsimo* 'washing', *kallyménos* 'covered') as opposed to those with a weaker 'verb-like' character (e.g. *kataktitís* 'conqueror'). Furthermore, lexical access results for Pseudo-Ws indicated that thematic features do impose constraints in deverbal word formation, which are evident at a later stage of lexical access compared to information regarding the grammatical category of the base. Results are discussed within a lexicalist framework and Manouilidou postulates the existence of a layered mental representation for certain lexical items in which their various properties exist at different levels and are not accessed at the same time, during the recognition process. Similarly, she postulates the sequential application of different constraints in word formation given that thematic constraints appeared to be processed after categorial ones (Manouilidou 2006: 172-174). Taken together, the results of the above studies show that processing of thematic features does take place in the lexical access of these nominals and that these features play a crucial role in the creation of new deverbal nominals, independently of the type of nominal.

Taking the above research into account, we seek to obtain additional evidence for the distinct processing of syntactic category vs. argument structure information in deverbal word formation. We compare data from two languages with distinct morphological properties and different status of constraints, namely English and Greek, and we seek to explore the extent to which these same two types of constraints operate not only cross-linguistically but also in both prefixation and suffixation.

3. The current study

Our experiments are designed to determine whether native speakers of English and Greek differentiate between Pseudo-Ws which violate different types of constraints, i.e. thematic (*redance*) and categorial (*softable*), in lexicalist terms, or distinguish between restrictions in the combination of affixes and functional heads determining syntactic category or argument structure preferences (in constructivist terms). The ultimate

goal is to tease apart the contribution of these two types of information in deverbal word formation. This would provide supporting evidence from an independent domain (psycholinguistics) for the existence of subprocesses in deverbal word formation and also verify whether all constraints or restrictions involved are perceived by speakers as equally strong. This is particularly interesting in light of the morphological differences between the two languages under investigation. Since the English word formation system and in particular its lexical category constraints on affixation are less strict than their Greek counterparts, we expect different patterns of rejection/acceptance, with higher acceptance of Pseudo-Ws (compared to Greek), reflecting a less rigid morphological system where general and specific constraints are more easily violable. The comparison between the two languages will allow us to examine the role of "strictness" or "coercability" as factors in evaluating novel derived words.

We examine this question by using an off-line acceptability judgment task and an on-line lexical decision task for Greek, and an on-line lexical decision task for English. The use of these two methodological tools taps into different kinds of knowledge, with the off-line acceptability task targeting speakers' conscious, metalinguistic knowledge about their language while the on-line task targets implicit, unconscious knowledge as it records speakers' reaction times while processing a linguistic stimulus.

3.1. Off-line task: Greek

The off-line task focused on patterns of rejection/acceptance of Pseudo-Ws, with respect to violations of thematic and categorial constraints.

Participants

Twenty-seven (27) native speakers of Greek volunteered to participate in the study. The group included males and females aged between 21 and 30 years old (mean age 23.6). They were all undergraduate and graduate Psychology students at the Aristotle University of Thessaloniki.

Materials

A total of 120 words were presented to the participants. Sixty (60) of them were Pseudo-Ws with categorial violations created using a noun with the suffixes *-tis* or *-simos,* e.g. **potiritís* 'glasser'*, *koutálimos* 'spoonable'. The remaining 60 were Pseudo-Ws with thematic violations created by pairing a non-agentive verb with the suffix *-tis,* e.g. **misi-tís* 'hat-er' or by pairing intransitive verbs with the suffix *-simos,* e.g. **tréksimos* 'runable'.

Procedure

Participants were presented with a typewritten list of Pseudo-Ws and asked to indicate for each one whether it could be a Greek word and, if YES, what it would mean. The request for a meaning to be supplied ensured against random acceptance or rejection of forms.

3.1.1. Off-line task: Results

Data analysis

Percentages of acceptance were calculated for all Pseudo-Ws with thematic or categorial violations, as well as for Pseudo-Ws grouped by suffix (*-tis, -simos*). As can be seen in Table 1, participants rejected the vast majority of Pseudo-Ws with both types of violations, with an acceptance rate of less than 30% for Pseudo-Ws with thematic violations and less than 10% for those with categorial violations. A one-way ANOVA, with type of stimulus as the independent variable and response type (YES or NO) as the dependent variable indicated that participants accepted significantly more Pseudo-Ws with thematic than with categorial violations [$F1(1, 26) = 10.65, p < 0.001; F2(1, 59) = 8.56, p = 0.01$]. This was true of acceptance rates for both thematic and categorial violations with *-tis* [$F1(1, 26) = 7.24, p < 0.01; F2(1, 29) = 5.82, p < 0.05$], as well as for those with *-simos* [$F1(1, 26) = 12.93, p < 0.001; F2(1, 29) = 11.02, p < 0.001$]. No significant interactions were found either by participants or by items. Thus, despite the overall low acceptance rates indicating that both constraints can be considered strong, there were differences in their relative strengths.

Table 1. Percentages of Acceptance for Pseudo-Ws with ThemViol. vs. CatViol.

Pseudo-Ws	Thematic Violations	Categorial Violations
with *-tis*	24.6%	14.1%
with *-simos*	31.6%	5.5%
AVERAGE	28.1%	9.9%

In summary, the findings of the off-line experiment suggested that participants differentiate between Pseudo-Ws that violate different types of constraints. Moreover, it appears that thematic constraints might be more violable than categorial ones. Finally, the off-line task did not reveal any particular effect for the specific suffixes used in the study (*-simos* vs. *-tis*). Pseudo-Ws with both suffixes yielded similar acceptance patterns with respect to the type of constraint violated, as the lack of significant interaction demonstrates.

3.2. On-line task: Greek

The on-line task addressed some of the same issues as the off-line experiment, but from an on-line processing perspective. Thus, one issue was whether native speakers would differentiate between Pseudo-Ws that violate thematic and categorial constraints in real time automatic processing or whether the differences observed in the off-line task would disappear due to time pressure.

In addition to Pseudo-Ws with ThemViol. and CatViol., the on-line task included other types of non-attested words bearing the same suffixes as the Pseudo-Ws with violations (i.e. *-simos, -tikós, -tis, -tós*). The first type were non-words (Non-Ws) that were formed by phonologically manipulating roots of existing derived words, thus keeping the suffix clearly detectable, e.g. *katakti-tís* > **kapakti-tís* ('conqueror' > *'conperor'). The Non-Ws provided a set of stimuli that could be validly rejected as not being real words. Also, reaction times (RTs) to Non-Ws could be compared with those to Pseudo-Ws that violate constraints in order to determine whether participants actually differentiated between words that seem possible and could have some kind of interpretation (Pseudo-Ws) and words that could by no means be interpretable (Non-Ws).

An additional type of stimuli was non-attested words without violations, such as *xtypitís* 'hitter', which we termed Novel-Ws. These Novel-Ws were formed on the basis of existing verb stems and the same suffixes used in the violation conditions. As their formation did not violate any constraints, they are considered potential words of Greek. The inclusion of Novel-Ws allowed us to measure processing differences between potential (Novel-Ws) and non-potential words (Pseudo-Ws and Non-Ws). The Novel-Ws also formed additional minimal pairs with Pseudo-Ws with ThemViol. As the Novel-Ws differed from Pseudo-Ws with ThemViol in the sense that they were non-attested but still totally appropriate, a comparison of the RTs for these two types of stimuli would permit us to better isolate the effect of thematic as well as categorial constraints. Table 2 summarizes the pertinent characteristics of the various stimulus types for the online experiment.

3.2.1. Method

An on-line single word lexical decision task was employed. In this task, participants sat in front of a computer and had to decide as quickly and accurately as possible whether or not the word strings that appeared on the screen were words of their language. Both RTs in milliseconds and response types (correct/incorrect) were recorded. The program Psyscope 1.2.5 for Power Macintosh was used to present the stimuli and record responses. Stimuli were presented in a standard lowercase Greek type-

Table 2. Summary of the characteristics of the stimulus set in the Greek on-line task.

Type of Stimulus	Characteristics	Examples
Non-Ws	non-existing stem existing suffix	**kapakt-itís* 'conperor'
Pseudo-Ws (CatViol)	existing stem existing suffix mismatch in terms of syntactic category	**karekla-tís* 'chair-er'
Pseudo-Ws (ThemViol)	existing stem existing suffix mismatch in terms of thematic features	**orimas-tís* 'maturer'
Novel-Ws	existing stem existing suffix no mismatch non-attested combination	*xtypi-tís* 'hitter'

face in 36pt font, in black text against a white background. Participants first saw a fixation cross for 200ms which was followed by a pause of 150ms. The target appeared immediately after the pause and participants had unlimited time to respond. All participants saw all items, and the order of presentation was pseudo-randomized for each participant.

Participants

Forty-six (46) male and female native speakers of Greek volunteered to participate in the study. The group ranged in age from 20 to 28 years old, with an average age of 23.4. All participants were students at the Aristotle University of Thessaloniki.

Materials

The stimulus set included:

Pseudo-Ws with *Thematic Violations*:

(a) 16 with the suffix *-tis* (*-er*) onto a verbal non-agentive base (**aimorragitís* 'bleeder').
(b) 16 with the suffix *-simos* (*-able*) onto a verbal base which does not receive an internal argument (**kathísimos* 'sittable').
(c) 16 with the suffix *-tós* (*-able*) onto a verbal base which does not receive an internal argument (**gerastós* 'ageable').
(d) 16 with the suffix *-tikós* (*-ive*) onto a verbal non-agentive basis (**orimastikós* 'maturive').

Pseudo-Ws with *Categorial Violations*:

(a) 16 with the suffix *-tis* onto a nominal base (**kareklatís* 'chairer').

(b) 16 with the suffix *-simos* onto a nominal base (**potírimos* 'glassable').
(c) 16 with the suffix *-tós* onto a nominal base (**kouvertitós* 'blanketable').
(d) 16 with the suffix *-tikós* onto a nominal base (**koutalitikós* 'spoonive').

Novel-Ws:
(a) 16 with the suffix *-tis* onto an agentive base (**xtypitís* 'hitter').
(b) 16 with the suffix *-simos* onto a base which receives an internal argument (**katharísimos* 'cleanable').
(c) 16 with the suffix *-tos* onto a base which receives an internal argument (**skoupistós* 'wipeable').
(d) 16 with the suffix *-tikós* onto an agentive base (**stolis-tikós* 'decorative').

In addition, 256 existing words were used as fillers, as well as 64 Non-Ws. All bases for Pseudo-Ws were controlled for familiarity and length. Overall, 37.5% of the items were ill-formed, 50% were familiar, well-formed words, and 12.5% were novel, unattested, but well-formed words.

3.2.2. On-line task: Results

Error Analysis

The error rate indicates how many times participants pressed the 'YES' button to indicate that unattested word formations were real words. Results are shown in Table 3. The numbers indicate mean percentages of 'YES' responses for each stimulus type.

Table 3. Percentages of 'YES' responses to non-attested words.

Novel-Ws	ThemViol	CatViol	Non-Ws
56.4	25.9	13.5	7.6

We conducted cross-stimulus type chi-square comparisons with the combined average error rates for all suffixes within a category and the results were as follows:

Novel-Ws vs. ThemViol.:	x^2=14.39,	df=3,	p<0.001
ThemViol. vs. CatViol.:	x^2=7.73,	df=3,	p<0.05
CatViol. vs. Non-Ws:	x^2=1.35,	df=3,	p=NS[5]

Thus, for the averaged data, with the exception of CatViol versus Non-Ws, our results indicate distinct patterns of rejection/acceptance for each category. That is, we find a continuum of acceptability, with the highest error rates for Novel-Ws, then ThemViol followed by CatViol and

ending with Non-Ws, albeit with non-significant differences between the last two word types. The ThemViol > CatViol > Non-W acceptance rates echoed the pattern found in the offline results.

To summarize the error analysis, the results support the existence of processing differences between ThemViol and CatViol, indicating that participants not only differentiate possible from impossible words, but that they also differentiate between Pseudo-Ws that violate different constraints and, to a certain extent, between Pseudo-Ws and pure Non-Ws. Thus, we have a first indication regarding the different status of the syntactic category of the base and the argument structure information in deverbal word formation.

Reaction Time Analysis

The dependent measure for all RT analyses was lexical decision latency for 'NO' responses reported in milliseconds. All reported RTs represent a mean of subject responses. Prior to the analysis, responses exceeding 2500ms were considered to be 'off-line' and were removed. Outliers (RTs below and above two standard deviations (SDs) from the mean) were also removed from the dataset. These exclusion criteria resulted in the loss of 4.5% of the data. Table 4 displays mean RTs and (SD) for each group of stimuli.

Table 4. Mean RTs in Millisecond with (SD) by stimulus type.

Novel-Ws	ThemViol	CatViol	Non-Ws
1037(221)	918(191)	867(207)	803(164)

Reaction time data were analyzed with linear mixed effects modeling procedures, which allowed us to account for variance by subject and by item within a single model (Baayen 2008). Predictor variables (stimulus type, length, and stem frequency) were centered to minimize effects of co-linearity. Analysis of the reaction time data yielded a significant effect of condition ($t = 20.1$, $p < 0.0001$).[6] Pairwise planned comparisons showed highly significant differences between stimulus types for all suffixes. Separate t-tests of these mean RTs are reported below (Bonferroni corrected alpha = 0.0083).

Novel-Ws vs. ThemViol:	t=-14.74,	$p< 0.001$
ThemViol vs. CatViol:	t=-9.59,	$p< 0.001$
ThemViol vs. Non-Ws:	t= 21.55,	$p< 0.001$
CatViol vs. Non-Ws:	t=11.12,	$p< 0.001$
CatViol vs. Novel-Ws:	t=-22.63,	$p< 0.001$
Novel-Ws vs. Non-Ws:	t= 32.86,	$p< 0.001$

The same continuum observed in the error rate analysis is also found for RTs. Participants took longest to process Novel-Ws, less time to respond to ThemViol, still less time to respond to CatViol and were fastest to respond to Non-Ws. Critically, comparing just the Pseudo-Ws with violations, those with ThemViol took significantly longer to process than those with CatViol.

Thus, the response time results add to the previous evidence from on-line and off-line error analysis, pointing towards distinct processing of category information vs. argument structure in a morphologically strict language such as Greek. In the remainder of the paper we will explore the question of whether such distinct processing is also observable in a language with more liberal word formation processes. The comparison with English will be on the basis of only an on-line lexical decision task, given that the Greek online data replicated the off-line pattern.

3.3. On-line Task: English

Given the underspecification of roots and the polysemy of affixes in English, it was much more difficult to identify affixes which only attach to verbal stems. Thus, in order to systematically manipulate the category selection restrictions and argument structure restrictions and to compare derived Pseudo-Ws that violate these restrictions with novel possible words, and with familiar derived words that obey these restrictions, we chose to focus on *re*-prefixation. As discussed above (section 1.2), *re*-prefixation in English is restricted to (a) verbs (providing us with a lexical category constraint), and (b) internal argument taking verbs (providing an argument structure constraint). In addition to the four stimuli types investigated in the Greek experiments, we included a set of familiar, fully grammatical, *re*-prefixed words, to ensure that an initial *re-* bigram was not a reliable cue for (non-)acceptability.

3.3.1. Materials

Materials consisted of 4 sets of 60 items, all beginning with *re-*. The 4 categories of items are exemplified in Table 5.

Category violating Pseudo-W stems are all unambiguous adjectives which do not have zero-derived verbal forms. Argument structure violating Pseudo-W stems are all unergative verbs or transitive verbs taking PP and CP complements (i.e. verbs with an <Ag> thematic structure). Novel complex word stems are all unaccusatives and transitives taking DP internal arguments (i.e., verbs with a <Th> thematic structure), and thus fully grammatical. In order to be classified as unattested, and thus novel for the present purposes, a word had to have an occurrence frequency of 0 in the British National Corpus (2007) and the Hyperspace

Table 5. Summary of the characteristics of the stimulus set in the English on-line task.

Type of Stimulus	Characteristics	Examples
Nonwords (NW Stem)	pseudoword stem existing prefix	**reclow* **revettle*
Pseudo-Ws (CatViol)	existing stem existing prefix mismatch in terms of syntactic category	**reflat* **rehappy*
Pseudo-Ws (ThemViol)	existing stem existing prefix mismatch in terms of verb argument structure	**resmile* **reboast*
Novel-Ws	existing stem existing prefix no mismatch non-attested combination	rehold rebother

Analogue to Language (HAL) corpus (Lund & Burgess 1996). All four categories of items were listwise matched for orthographic length. All conditions except the nonword stem condition were listwise matched for stem surface frequency (HAL corpus).

In addition to the 240 critical items, an additional 350 words and pseudo-words were included as fillers. These fillers were real or pseudo-word verbal stems, affixed with other affixes, such as *un-*, *-able* and *-ee*, as well as a set of familiar complex words prefixed with *re-* (*refill*, *recount*) and monomorphemic words beginning with <*re*> (*remorse, repeat*), included to help balance the ratios of possible to impossible *re-* items. Thus, only 56% of the total set of items began with *re-,* and among those, only 60% were ill-formed. Among the filler items 40% were ill-formed. Overall, 51% of the items were ill-formed, 38% were familiar, well-formed words, and 11% were novel, unattested, but well-formed words.

3.3.2. Method

Participants

Thirty native speakers of UK English participated in the experiment ranging from 18 to 56 years old (mean = 23.5). Participants performed a single word lexical decision task, as in the Greek experiment. Each trial consisted of a fixation cross which appeared for 330ms, followed by the target letter string, which appeared until the participant pressed a response button, or 2500ms had elapsed (whichever came first). Letter strings were displayed in 36pt font, in white text against a black background. Trial presentation was pseudo-randomized and all

participants saw all trials. DMDX (Forster & Forster 2003) was used to control stimulus presentation and record response accuracy and time. Participants were reimbursed £5 for their participation.

3.3.3. Results

Lexicality Decision Analysis

The proportion of trials which participants judged to be acceptable words of English is in Table 6.

Table 6. Percentages of 'YES' responses to non-attested words.

NOVEL-WS	THEMVIOL	CATVIOL	NON-WS
64.6	21.4	9.4	14.9

As above, we conducted cross-stimulus type chi-square comparisons with the combined average error rates for all suffixes within a category and the results were as follows:

Novel-Ws vs. ThemViol.: $x^2=145.07$, df=3, $p<0.001$
ThemViol. vs. CatViol.: $x^2=28.03$, df=3, $p<0.025$
CatViol. vs. Non-Ws: $x^2=0.83$, df=3, p=NS

All pairwise comparisons between stimulus types were significant, except the contrast between CatViol and Non-Ws. In contrast to the Greek judgment data, English participants were more permissive in accepting the novel words and the non-word stem words, but had very similar patterns of acceptance across the two languages. The critical comparison is between the acceptance rates for the CatViol prefixation items, and the ThemViol prefixation items. Just as in Greek, English participants are about twice as likely to accept the argument structure violations as the lexical category violations.

Reaction Time Analysis

As above for the Greek data, trials where the response time was further than two standard deviations above or below the mean response per subject and condition were excluded from analysis, resulting in the loss of 2.6% of the data.

Table 7 reports the average response times by stimulus type. ThemViol were judged more slowly than CatViol, and the Novel-Ws were judged yet more slowly than that, a pattern that echoes the Greek data set. What is different between the languages is the rejection time for Non-Ws in English, which is slower than both types of Pseudo-Ws.

Table 7. Mean and (SD) Response Times in milliseconds.

Novel-Ws	ThemViol	CatViol	Non-Ws
1081(425)	1022(403)	973(359)	1073(459)

A linear mixed effects model with subject and item as fixed effects and stimulus type (centered) as the predictor variable and response time (log transformed) as the dependent measure revealed a significant effect of stimulus type ($t=2.54$, $p<0.02$). Pairwise planned comparisons showed significant differences between stimulus types for all comparisons, except Novel-Ws vs. Non-Ws. Separate t-tests of these mean RTs are reported below (p values that are significant given a Bonferroni corrected alpha = 0.0083 are starred*).

Novel-Ws vs. ThemViol:	t = -4.1607	$p< 0.001$*
ThemViol vs. CatViol:	t = -3.7868	$p<0.001$*
ThemViol vs. Non-Ws:	t = -3.4611	$p<0.001$*
CatViol vs. Non-Ws:	t = -7.1393	$p<0.001$*
CatViol vs. Novel-Ws:	t = -8.0577	$p<0.001$*
Novel-Ws vs. Non-Ws:	t = 0.5169	$p=0.6$

4. Discussion

The main goal of the present investigation was to isolate the contribution of syntactic category vs. argument structure information in deverbal word formation by examining whether native speakers differentiate between Pseudo-Ws which violate different types of constraints corresponding to these kinds of information. The investigation included Greek and English, two languages with distinct morphological properties in terms of permissiveness of affixation. With respect to the critical question, results from both languages indicated that participants are more likely to reject Pseudo-Ws violating syntactic category restrictions (*rehappy*) than Pseudo-Ws violating argument structure information (*relaugh*), and both types of violation are rejected much more frequently than Pseudo-Ws which do not violate either of these restrictions. In both English and Greek, response times mirror these rejection rate patterns straightforwardly, and the comparisons between conditions are highly significant. The only difference between languages is the response to the non-word stem items, which are slower to judge and less likely to be rejected in English than they are in Greek. Figure 1 summarizes this pattern of results.

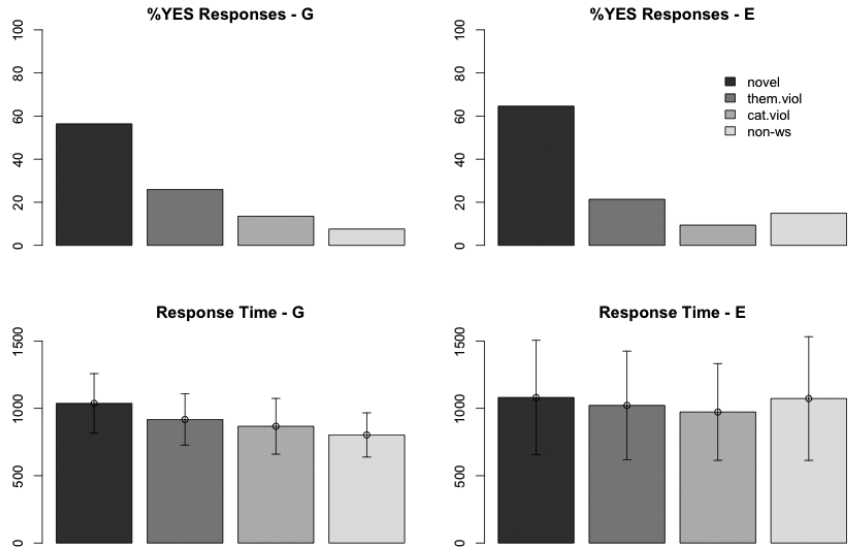

Fig. 1. Comparison of the online acceptance Rate and RT data in Greek (G) and English (E). Error bars in the second row plot SDs.

Given these findings, we can make some general remarks about pseudoword processing and accessing different kinds of information. First of all, it seems that speakers of both languages use their knowledge of morphology to process non-attested deverbal word formations, a fact which evidently supports a model of lexical access in which all morphologically complex letter strings are parsed into their constituent morphemes and it is in accordance with the literature on early, robust[7] decomposition[8] (see Rastle & Davies 2008).

With respect to the question of what properties of stems and affixes are available at early stages and if there is a distinction between them, results demonstrate that processing time is modulated not only by morphological structure but also by the different kind of information processed, with syntactic category processing being detected fairly easily compared to any other type of information, such as thematic information, a pattern which holds for two morphologically distinct languages such as English and Greek. Both the error analysis and the RT analysis robustly point towards a stratified processing of various features. It is clear that, for both languages, each type of constraint has its own contribution to deverbal word formation and its violations result in distinct types of

Pseudo-Ws which are perceived as separate entities by speakers and are processed in a different way during lexical access. Surprisingly, however, English participants were not more liberal than Greek participants in accepting category and argument structure violating affixed words (Figure 1, top row). This suggests that although English may be more permissive about word formation in general (a claim supported by the very high acceptance rates for the Novel-W items), there is no evidence that English speakers are more willing to violate selectional restrictions on affixation.

The findings are in accordance with the results reported in the literature by Manouilidou (2006) for Greek and also Dikker *et al*. (2010) and Whiting *et al*. (2013) for English about the separate, early, fast access of syntactic category information in derived words. Specifically, speakers of both languages clearly differentiate between Pseudo-Ws violating information about grammatical category (CatViol) and argument structure (ThemViol) and this is done in distinct processing times. That is, speakers isolate processing of syntactic information of the base, as the different acceptance rates and RTs between CatViol and ThemViol show, going towards the same direction as Dikker *et al*. (2010) and Whiting *et al*. (2013), who advocated for the precedence of syntactic category processing in complex word formations. The unequivocal pattern of results from two languages with inherent differences in their derivational system (see section 1.2) is suggestive for the processing demands each constraint imposes, independently of the language, further pointing to a universal way of processing a complex pseudo-word.

Hence, unless further research proves otherwise, we could assume that such layering (syntactic category information first, other-than-syntactic information afterwards) is not unique to the processing of deverbal nominals, but is a more general processing strategy of accessing lexical units which carry a variety of information. If this is the case, then combined results show a very general pattern that is plausibly reflecting something universal about the way grammatical category information is stored/accessed vs. the way verb argument structure information is stored/accessed. In other words, by assuming that the layers of access correspond to layers of representation or that units of access correspond to units of representation, we can make a number of claims about word formation processes and the organization of the lexicon based on the evidence from lexical access obtained through the present investigation.

Specifically, with respect to layers of access of derived words, it seems that if various types of information appear to be processed at different stages in word recognition and if processing specifications are a reflection of word formation processes, then we will have to assume

that word formation also involves the sequential application of different constraints (along the lines suggested by Manouilidou 2006: 176). For instance, for all the suffixes used in the present study, the thematic information appears to be processed after categorial constraints. Viewed from the perspective of word formation, thematic constraints would appear to apply after the application of categorial constraints. This would have further implications for word formation, suggesting a stage-like process similar to one for lexical access. The idea of a stage-like organization in word formation is not new. Within the framework of Lexical Morphology and Phonology, the lexicon is divided into various levels (Kiparsky 1982) or strata (Mohannan 1986), which classify and group together the application of morphological and phonological processes of word formation. These levels or strata span between the lexicon and syntax and divide lexical structure into sublevels, each of which includes a morphological and a phonological part. Also, similar predictions can be made by a constructivist theory such as Distributed Morphology (e.g. Halle & Marantz 1994, Marantz 1997), which makes a clear distinction between initial adjunction of a root with a category assigning head, and subsequent projection/licensing of argument structure. Such an approach postulates an ordering of operations and a size of structure difference which is clearly reflected in the current data set from both Greek and English.

In any case and in any theoretical framework, the current study does support sequential access of information in word recognition, which might reflect a sequential application of constraints (or type of information) in constructing a new lexical item. Future investigation should seek additional support by including evidence from more affixes and more languages.

5. Conclusion

The current study investigated the contribution of syntactic category of the base and argument structure information in deverbal word formation by looking at two morphologically distinct languages, English and Greek. Results unequivocally suggest that, setting aside the particularities of each language as well as the particularities of suffixation vs. prefixation, participants process syntactic category information before processing argument structure information. This is suggestive of a structured mental representation where various features can be accessed via distinct operations and at distinct points of time.

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Notes

[1] This notation is for convenience's sake and is not meant to represent an analysis of the formal properties of lexical aspect.

[2] There is also a third camp supporting the view that both decomposed and whole word forms are available, with each being accessed under different circumstances (e.g. Chialant & Caramazza 1995; Schreuder & Baayen 1995).

[3] These studies either highlight various constraints such as the position of the suffix, *gasful* vs. *fulgas* (Crepaldi, Rastle, & Davis 2010) or stress the role of real morphemes in masked priming, *prénom* vs. *danom* (Giraudo & Grainger 2001) or bring into attention the role of orthographic overlap (Giraudo & Voga 2013). Although they provide valid counter-examples, they do not negate the current trend in psycholinguistics, which predominantly supports full decomposition.

[4] These studies are, of course, considerably more naturalistic than single word lexical decision studies, but the top-down expectation driven processing makes it difficult to determine what information about lexical category and argument structure can be activated on the basis of the affix and stem alone.

[5] The lack of significant differences between CatViol and Non-Ws stems from the suffixes *-tos* and *-tikos* for which CatViol and Non-Ws did not differ significantly. In contrast, the other two suffixes yielded significant differences between these two categories, i.e. CatViol-*simos* vs. Non-Ws-*simos*: $x2 = 4.05$, $p < 0.01$ and CatViol-*tis* vs. Non-Ws *tis*: $x2 = 5.47$, $p < 0.01$.

[6] Because it was not possible to match for word length and stem frequency across conditions in creating the stimuli, due both to the properties of Greek stems, and to the unavailability of a lexical frequency database for Greek at the time the materials were created, we conducted statistical analyses to ensure these factors did not interact with our variable of interest. We found that adding length as a predictor to our linear mixed effects model did account for significant response time variance ($t=4.8$, $p< 0.0000$), but when we crossed length and stimulus type, we found no significant interaction ($t = 1.9$, $p=0.0597$), and model comparison revealed no significant increase in model fit. Stem frequency had no significant effect on response time at all ($t = -0.4$, $p=0.5036$).

[7] Our study is not a time-course study, thus, in a very strict sense we have no means of determining what kind of information is processed first and what kind is processed second. However, our four types of stimuli are constructed in a way essentially consisting in "minimal pairs" (each stimulus type adding an extra feature going from pure non-words to possible words), thus allowing us to interpret the extra processing time as a step further in the process of having a possible word. In this sense, we do believe that the current study falls within this body of literature.

[8] The fact that pseudowords are always accessed through decomposition into

their constituents is not new. It has already been claimed by Caramazza et al. 1988 and Schreuder & Baayen 1995. Moreover, a number of studies indicate that additional morphological processing differentiates those Pseudo-Ws with partial morphology from those entirely composed of existing morphemes of a language (Laudanna et al. 1992; Burani et al. 1999). For instance, a word like *dref-able will be more easily rejected than *sleep-able.

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