There's No "Tea" in "Team": The effects of morphological complexity on word naming

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Abstract

This study used a word constituent-priming word naming paradigm to determine the planning units necessary for encoding word representations into speech. This study demonstrates that compound words use their constituent word forms as planning units of speech. This effect of morphological structure was seen not only for semantically transparent compounds but also for semantically opaque compounds with shorter onset latency when primed. These effects were robust for all compounds as well as for novel compounding. These results support a morphological based encoding model of speech production.

Keywords: encoding, priming, semantic transparency, lexical access, word production

1 Introduction

*"There's no **I** in team".* This is a parable we have often heard emphasizing that it's not the individual that matters, but it is cooperation of all its members. Research in psycholinguistics, but most critically in lexical processing, has several variations on this theme of how individual units contribute to an overall representation. The classic debate over whole-word representation (Butterworth, 1983) versus morpheme storage (Taft & Forster, 1975)

has persisted over the past forty years along while both camps have discovered more evidence for their claim. On the one hand, in modern debates the former side ascribes to the *supralexical hypothesis* (Giraudo & Grainger, 2000, 2001) that maintains the notion of whole-word representation-first in lexical access, only then does this access lead to morphological representation downstream.

On the other hand, the latter side, which ascribes to the *sublexical hypothesis* or morpheme access-first, has formed factions over the semantic relevance in morphological composition. Marslen-Wilson et al. (1994) proposed a model where a morphologically complex was decomposed into its morphemic constituent if and only if the composition of the morphemes was *semantically transparent* to the complex word's overall meaning. For example, in a series of cross-modal repetition priming tasks, Marslen-Wilson et al. (1994) found that words such as ***department***, which have an *opaque* morphological structure, do not prime their constituent word form ***depart***, but words like ***departure***, which have a transparent morphological structure, do exhibit priming effects on their constituent morphemes resulting in faster reaction times to a lexical decision.

In contrast, Rastle et al. (2004) found evidence that in early stages of lexical access, we do, in fact, have access to all of a word's constituent word forms regardless of their *semantic transparency*, or their semantic contribution to the word's overall meaning. Using *masked priming* with lexical decision, a technique which uses brief exposures of a stimulus to probe at subliminal and automatic processes, Rastle et al. (2004) found that there were significant but indistinguishable priming effects of faster reaction times to a lexical decision for both opaque and transparent words when compared to their mono-morphemic simple words counterparts. This demonstration asserted that word forms are accessible in early stages of lexical access with the constraints of morphological well-formedness. That is, mere orthographic overlap is not sufficient for modulating lexical access.

Most research on morphological processing in lexical access has been conducted in a comprehension domain, often with participants making some linguistic judgment on a given word. These studies probe interesting questions about how language is processed and understood but it has left us begging the question of how these words are produced in speech. There are only a handful of studies investigating the role of morphology in production. Levelt et al. (1999) proposed a multi-stage model of lexical access for speech production where we begin with the conceptualization of the lexical item, which leads to its retrieval, and then ultimately to its articulation. The basis of the Levelt et al. (1999) model works on the independence of the conceptual system and the articulatory motor system. These systems are interfaced with their respective encoding stage. The conceptual system has a morpho-phonological encoding stage that is responsible for giving form to the concept while the articulatory motor system is fed input from phonetic encoding stage where articulatory gestures are planned for speech. The crux of this model lies at a separation of meaning from its articulatory realized form. In order to marry these two distinct systems, it is critical to understand the nature of these encoding processes that are involved in transforming concepts into a fully articulated form.

1.1 Encoding

Here, we are taking the notion of *encoding* to be a set of operations necessary for interpreting information from one domain, (e.g. form representation), and expressing its message in another domain (e.g. articulation). Focusing in on the representational level, its encoding provides a crucial stage for production: providing the planning units of speech. For complex word production, it is unclear what the planning units are for speech production. Models vary in their encoding specificity ranging from phonological only models to those with a mediating morphological stage. Meyer (1990, 1991) found that repetition of phoneme clusters alone can lead to preparatory effect in production with results suggesting that syllables are planning units for speech. In contrast, in Levelt et al. (1999) model, it proposes that the encoding process involves a stage of morphological access where word forms are designated as planning units, but the model does not specify whether the word forms are accessible in words with an opaque structure. Similarly, Roelofs & Baayen (2002) reported that the production of polymorphemic words relied on the use of their morphemic constituents for the encoding process supporting a morphological "autonomy" view. Using an on-line preparation paradigm, they concluded that these word forms are not only used as planning units but that they are accessible regardless of the word's semantic transparency. Dohmes et al. (2004) provide additional support for a morphologically-mediated encoding. In a picture-naming task, they found a strong facilitation in picture naming for complex words that suggested that there is a form representational level in speech production where morphologically complex words are represented by their constituent morphemes independent of semantic transparency.

1.2 Priming

Although previous studies have presented evidence of morphemic effects on production, it remains unclear to what extent are these word forms modulated in production. Word duration and onset latency are acoustic properties that have been implicated as modulatory indicators of lexical access (Arnold et al., 2012). Gahl (2008) discusses how word duration and shortening of frequent words have been shown to be markers lexical processing.

In their study, Gahl (2008) showed that word frequency can modulate the word duration of homophones demonstrating that there are distinctions in these words' representations even when they are shown to have the same phonetic realization. These effects of word frequency have found their analog in repetition priming. Bybee (2001) describes *repetition priming* as an articulatory routinization where "neuromotor routines become more compressed and more reduced". Priming, a phenomenon observed as a modulation in response due to repeated exposure to a stimulus, can be used to probe at the representation status of a previously activated word. This routinization would suggest that words that have been repeated would result in shorten durations and as well as a host of other articulatory effects (Gahl, 2008; Fiorentino & Poeppel, 2007; Bard et al., 2000; Arnold et al., 2012).

The body of literature is steadily growing demonstrating these effects priming on production. Arnold et al. (2012) used images and visual cues to prime different referents in a discourse and found that this priming modulates the production of the referent resulting in reduction in their duration. Balota et al. (1989) explored the effects of priming of related items parametrically using various SOAs. Using associative priming, they found that a related response cue led to a reduction in the target word's production duration. Interestingly, they found that SOA of the associated cue to be independent of the production duration of its target. This model predicts that there is some semantic governance for word production where only semantically associated items lead to facilitatory effects. The results from this study pattern with a semantic governance view (Marslen-Wilson et al., 1994) while diverging from the morphological autonomy view (Roelofs & Baayen, 2002).

The study of these effects on the encoding operation in word production has largely remained uncharted territory. Few studies have looked at the mechanism of how the internal structure of word may lead to its production (Roelofs & Baayen, 2002). Findings in comprehension present disagreements in the role of semantics in morphological structure (Marslen-Wilson et al., 1994; Rastle et al., 2004). Our study takes this a few steps forward to ask what is the nature of this boost to for having morphological structure. Does this reflect the use of word forms as planning units of word production? If so, can we modulate the representation status of these word form independent of the word meaning?

Our study used a word naming paradigm to assess these prediction. In this study, we used spatially unified, bi-morphemic, compound words since they provide a rich testing bed for assessing these predictions. We compared these compounds to mono-morphemic simple words to evaluate the nature of the morphological structure. These simple words were selected to have an embedded word within its orthography and they were selected to have overlapping phonology. This will test whether these effects can be reduced to overlap in orthography or phonology. In addition to comparing our compounds to simple words, we included a selection of novel compounds to test the effects of planning in light of no prior experience and and with a strictly, and compulsory, transparent interpretation. To test whether semantics constrain the accessibility of word forms within compound words, we varied the degree of semantic fit of its constituents to its overall meaning. We examined *onset latency*, the reaction time to speak, to evaluate the effects of morphological structure and its semantic constraints based on Fiorentino & Poeppel (2007), which predicts that since RT is sensitive to lexical processes, that compounds will differ from single words, due to the properties of the constituents rather than the whole word, whereas a non-decompositional account predicts no differences due to word structure. If there is a decomposition effect, onset latency can be used to disentangle whether decomposition occurs at an early or a late stage of processing. In an early decomposition model, we expect there to be a faster latency times for all compounds regardless of semantic transparency because this occurs before access to semantics. If this reflects a late decomposition model, where decomposition follows lexical access, then we do not expect decomposition to occur for opaque compounds since the semantics would constrain the access of the word forms related to the compound to those that are meaningfully related.

Given our assumption that word forms are used as planning units for speech, we tested whether we can modulate the representational status of these word form using a priming paradigm where the constituent is used to prime the underlying structure of its compound word. This study aims to distinguish whether the decomposition of the compound words occurs early or late. The current literature posits three possible encoding models of production for our results: (1) a syllable-based model, which predicts that there will be a reduction in constituent duration regardless of morphological structure; (2) a morphology-based model, which predicts that there will be a reduction in constituent duration for all morphologically structured words regardless of their transparency but not for simple words; (3) a morpho-semantics based model, which predicts that there will to be a reduction in constituent duration but only for words with a transparent morphological structure. This study argues for an early decomposition model with a morphologically-based encoding operation where word forms are used as planning units for production regardless of semantics.

2 Methods

2.1 Stimuli

A sizable corpus of compounds were compiled from prior studies (Drieghe et al. (2010); Fiorentino & Poeppel (2007); Fiorentino & Fund-Reznicek (2009); Juhasz et al. (2003)) and were normed using a semantic relatedness survey administered through Amazon Mechanical Turk. The semantic relatedness survey asked participants to rate on a Likert scale from 1 to 7 how related the meaning of the one of compounds' constituents is to the compound itself where "1" was not related and "7" was very related. 20 participants were randomly given only one constituent per compound to judge. The ratings were largely consistent with prior work.

We defined constituents as semantically opaque (e.g. deadline) with a score between 1 to 3 and semantically transparent (e.g. dollhouse) between 5 to 7. Compounds were considered fully opaque if their summed ratings were 1-6 and fully transparent if 10-14. For example, the opaque compound 'deadline' received a summed rating of 3.76 with 'dead' contributing a transparency rating of 1.44 and 'line' contributing a rating of 2.32. Similarly, the compound 'dollhouse' received a summed rating of 11.79 with 'doll' contributing a transparency rating of 6.47 and 'house' contributing a rating of 5.32. Sixty fully opaque and sixty fully transparent compounds were randomly selected from the corpus.

In addition to the opaque and transparent compounds, we included novel compounds to look at production effects for words with possible morphological structure but with no established overall meaning. Sixty novel compounds were randomly generated using the remaining compounds from the relatedness survey. These novel compounds were generated by concatenating randomly selected constituents from their remaining respective pools. Since these constituents are words that are likely to be compounded with others, they make good candidates for novel word formation. To prevent the random formation of an existing word, the word frequency of these compounds were checked using the English Lexicon Project's word frequencies (Balota et al., 2007).

Lastly, to test whether duration reduction was merely a function of phonological overlap, mono-morphemic words consisting of an embedded but no possible internal morphological construction (e.g. BROTHel), which we will simply referred to as mono-morphemics were added for comparison. The mono-morphemic words were pooled from Rastle et al. (2004) and the English Lexicon Project(Balota et al., 2007), were selected to have overlapping punctuation between the mono-morphemic and its embedded word (e.g. HATCH-hatchet vs. CORD-cordial). Sixty mono-morphemics were selected for this study: thirty of them having the embedded words at the beginning of the word (e.g. HATCH-hatchet) while thirty others with the embedded words at the end (LOG-dialog) .

2.2 Experimental Design and Task

This study contrasted four different word types, each with 60 items: mono-morphemics, and transparent, opaque, and novel compounds. These word types were compared in two types of priming, repetition and constituent. For the repetition priming condition, the word of interest was shown as both the prime and the target as compared with the constituent priming where the constituent of word (for this study, first-constituent only) is used as a prime for its whole word target. These priming conditions were compared to their semantically unrelated controls. Each word appeared once per block in one of the four different conditions across four blocks. They were counterbalanced so that all words appeared in all conditions per subject and were latin-squared for condition order across subjects producing a completely within-subjects, fully factorial design: Word Type (4) × Constituency (2) × Priming (2).

The study used a repetition priming paradigm with word naming as its task. Psychtoolbox (Brainard, 1997) was used for the presentation of stimulus. In this task, the trial begins with a fixation cross, which appears in the center of the screen, followed by a prime then a target. Prime words are presented in all capital letters while target words are presented in lowercase letters. All of the visual presentations are for 300 ms with an inter-stimulus

	Transparent		Opaque		Novel		Simple	
	prime	target	prime	target	prime	target	prime	target
control	doorbell	teacup	heirloom	hogwash	keybook	ladyfork	mailbox	spinach
identity	teacup	teacup	hogwash	hogwash	ladyfork	ladyfork	spinach	spinach
control	door	teacup	heir	hogwash	key	ladyfork	mail	spinach
constituent	tea	teacup	hog	hogwash	lady	ladyfork	spin	spinach

Table 1: Design Matrix

interval of 600ms. The objective of the participant is to read aloud the target word in each trial. The next trial does not proceed until a response is uttered. The onset latency was measured from the presentation of the target word to the threshold activation of the voice trigger. Their production was recorded from the point at which voice trigger was activated. Each participant was presented with 960 trials: 60 words in each of four word types counterbalanced for each of the four condition. This study includes 17 participants who were recruited from the New York City community.

2.3 Results [1]

In this study, the effects of priming on both naming latency and word durations were analyzed using a repeated-measures ANOVA. Naming latencies were defined as the duration from the visual onset of the target stimulus to the onset of speech.

To obtain the duration measures from the production data, we use the Penn Forced Aligner (Yuan & Liberman, 2008). We provided transcripts for each target word where each constituent was considered a separate word. A textgrid was created for each target word with boundary markings for both the phone and word, which were generated using the Hidden Markov Model Toolkit (HTK). The audio was checked for accuracy of the target word production. These textgrids were hand-corrected (1) in Praat (Boersma, 2002) with the following requirements:

1. The offset of the word boundaries were determined to be where there was no energy

[1] see Appendix for supplementary tables.

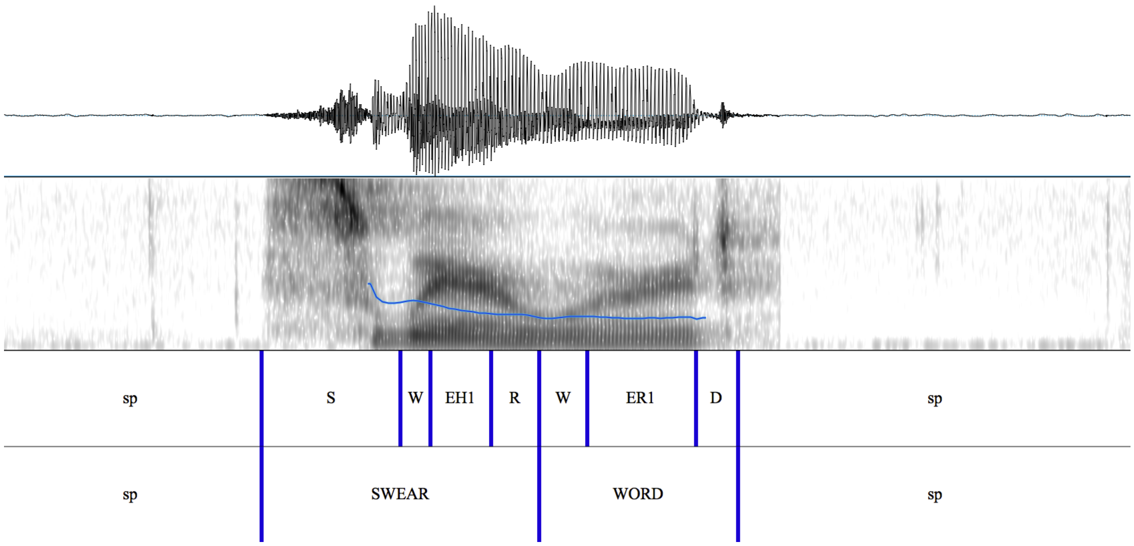

Figure 1: Boundary labeling for target word

in the spectrogram and waveform.

2. the offset boundaries of words containing a stop were marked before aspiration to maintain consistency across speakers.

3. incorrect pronunciation or incorrect word utterance was marked and eliminated from analysis (Morrill, 2012).

4. a hesitation or pause before or after the test word that disrupted the fluency of the reading (Morrill, 2012).

These criteria were allow uniformity with proper discretion from the author.

2.3.1 Onset Latency

Analysis of onset latency time for identity condition revealed a very robust, repetition priming effects such that naming latencies were shorter for the target when it was primed $[F_1(1,16) = 77.24, p < .001]$. There was no interaction of wordtype $[F_1(1,16) = 0.93, p > .1]$. Unsurprisingly, these findings are consistent with all predicted models.

Analysis of onset latency time for the constituent condition revealed a significant priming effect such that naming latencies were shorter for the target when it was primed $[F_1(1,16) =$

40.06, $p < .001$]. This indicates that constituent priming has an effect on all of the wordtypes. The difference presented is calculated by subtracting the primed condition from the unprimed to reflect the amount of speed up in processing due to priming.

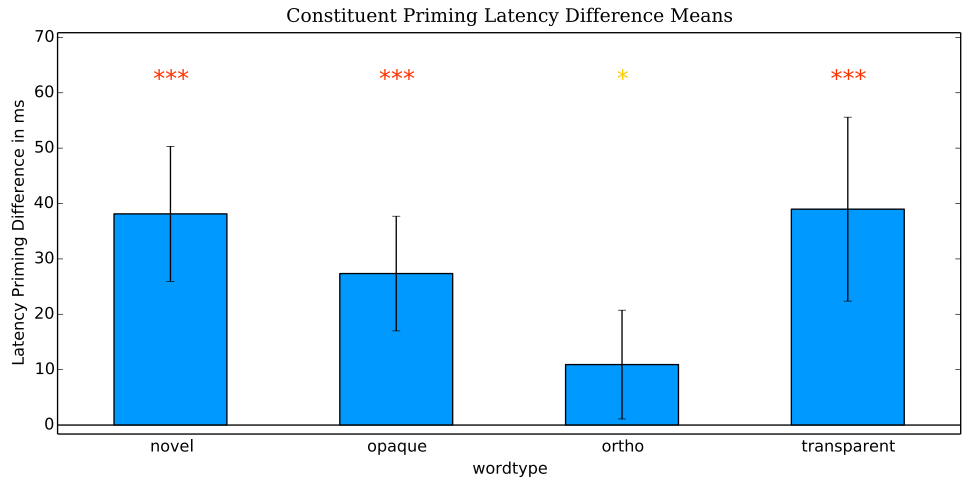

Figure 2: Constituent Priming Onset Latency Difference Main effects plots

However, there was a significant wordtype by priming interaction such that naming latency were faster for transparent, opaque and novel compounds but not for the simple words [$F_1(1, 16) = 6.93$, $p < .001$]. We can attribute the effect of priming seen for the simple words to that of overlapping form but this interaction occurs above and beyond this effect of overlap. These results explain away that these constituent priming is only due to form overlap and supports our claim that these word forms play a role in planning speech.

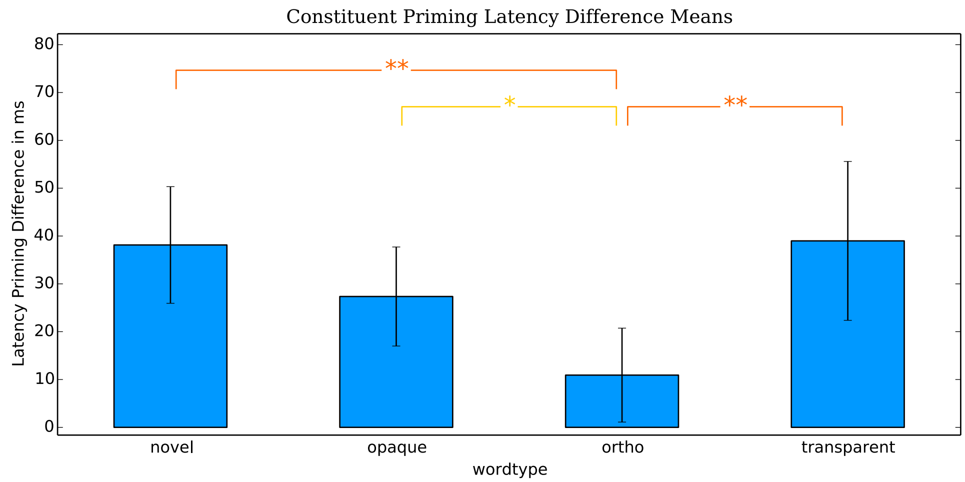

Figure 3: Constituent Priming Onset Latency Difference Interaction plots

This particular pattern of results was confirmed with planned comparisons using the difference from the constituent conditions for each compound wordtype compared to difference from the constituent conditions for the simple words (2).

	opaque	ortho	transparent
novel	$t(34)_{34} = 1.35$ $p = .187$	$t(34)_{34} = 3.48^{**}$ $p = .001$	$t(34)_{34} = -0.08$ $p = .935$
opaque		$t(34)_{34} = 2.30^{*}$ $p = .027$	$t(34)_{34} = -1.19$ $p = .243$
ortho			$t(34)_{34} = -2.91^{**}$ $p = .006$

Table 2: Pairwise Comparison table for Constituent Priming Latencies

The onset latency effect is largely consistent with the masked priming literature on word recognition where there is a processing benefit associated with having a morphologically structure word that is not seen in simple words (Rastle et al., 2004; Taft, 2004; Morris et al., 2007; McCormick et al., 2008). These results build upon Roelofs & Baayen (2002) findings where word forms are used as planning units for production.

2.3.2 Duration

Due to the nature of hand-correcting textgrids, the analysis of the word duration is currently incomplete. The data processing is ongoing. Currently, 50% of the data for six participants have been hand-corrected. Below, we have completed the same analysis over this subset of data. Since this dataset is sparse, there is a large amount of variance in the measurement, hence, the model is too unstable to provide any reliable estimates.

Our study would predict that the duration data should pattern with the onset latency duration where we have duration times will be reduced for compound words but not for simple words.

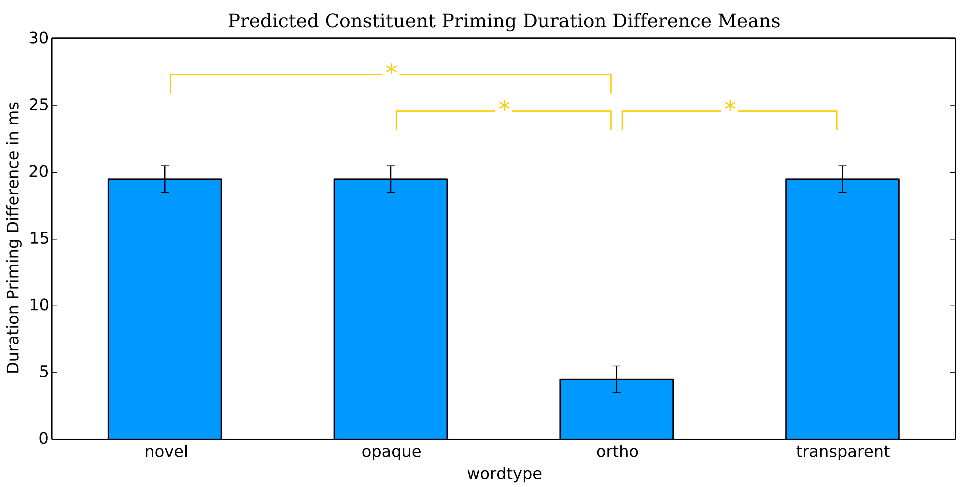

Figure 4: Predicted Constituent Priming Duration Difference plots

Our data analysis shows that it is premature to analyze the results due to the large variance in our estimates.

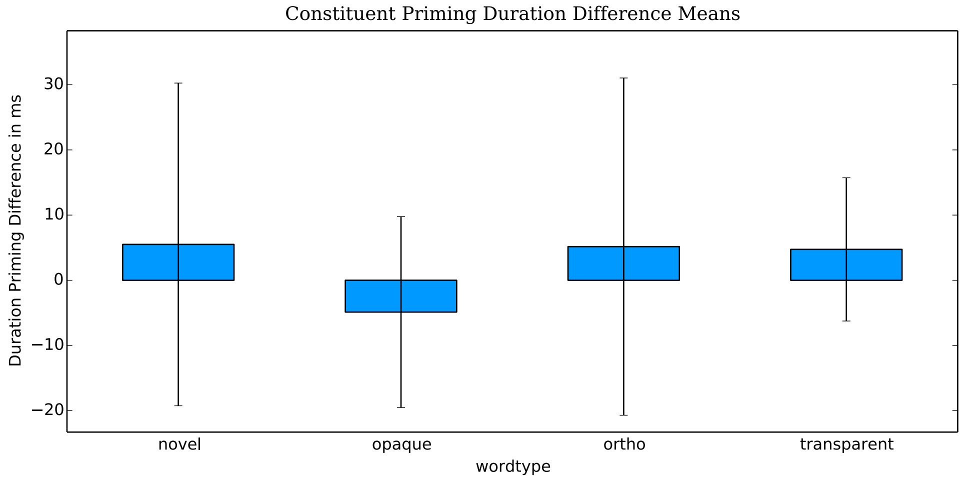

Figure 5: Constituent Priming Duration Difference plots

If the results show a constituent priming effect for the opaque compounds (e.g. HOG-hogwash), then these word forms internal to the compound function like the word forms in isolation. This would confirm that there is access to the word forms in morphologically structured word regardless of their semantic contribution and that these word forms are not functioning as homophones but are the word forms themselves.

3 Conclusion

The results from our study fit in nicely with the morphology-based encoding interpretation where word forms are used as planning units regardless of their semantic contribution to the overall word meaning. This is largely consistent with the mounting evidence in the lexical decision literature where the first stages in parsing require segmentation of morphologically structured words into their constituent word forms prior to any access of their semantics. This study discredits syllable-only encoding hypothesis since there are still morphological effects even after matching for phonological and orthographic overlap. This is also evident in novel compounding where these words show evidence of word form access even in the absence of semantics.

This study presents clear evidence that there is a stage in lexical access that follows from lemma selection (Levelt et al., 1999) responsible for organizing and planning of speech in units of word forms. This stage is not constrained by semantics of the word forms' contribution This study demonstrates the crucial role that morphology play a role in both parsing and production.

4 Appendix

	SS	**df**	**MS**	**F**	**p**
wordtype	6451.20	3	2150.40	6.81***	< .001
condition	110985.57	1	110985.57	77.24***	< .001
wordtype x condition	1021.75	3	340.58	0.93	.431
Total	1345197.48	143			

Table 3: ANOVA table for Identity Priming Latencies

	SS	**df**	**MS**	**F**	**p**
wordtype	5320.74	3	1773.58	3.42*	.024
condition	29958.08	1	29958.08	40.06***	< .001
wordtype x condition	4612.17	3	1537.39	6.93***	< .001
Total	1208222.91	143			

Table 4: ANOVA table for Constituent Priming Latencies

	SS	**df**	**MS**	**F**	**p**
wordtype	1509.10	3	503.03	2.15	.137
condition	57.42	1	57.42	0.51	.506
wordtype x condition	184.03	3	61.34	0.13	.942
Total	54919.61	47			

Table 5: ANOVA table for Identity Priming Duration

	SS	**df**	**MS**	**F**	**p**
wordtype	6452.90	3	2150.97	10.81***	< .001
condition	83.05	1	83.05	0.96	.372
wordtype x condition	226.55	3	75.52	0.20	.894
Total	52777.32	47			

Table 6: ANOVA table for Constituent Priming Duration

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