Parsing and semantic opacity *

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Abstract. This paper addresses the question how semantically opaque complex words with low full-form frequencies and high constituent frequencies are processed in visual word recognition. Paradoxically, the frequency imbalance between the full form and its constituents favors rule-based processing for such words, while at the same time rule-based processing cannot provide access to their idiosyncratic meanings. Three experiments are reported that address the question how such words are processed. These experiments show that, surprisingly, processing of phonologically and orthographically regular complex words proceeds on the basis of their constituents, irrespective of semantic transparency, but only when based on productive word formation patterns. At the same time, the opaque meanings of such low-frequency complex words become available before the meanings of their high-frequency constituents. We propose to understand these results in terms of an integration mechanism at the level of the lemma nodes in the central lexicon.

Keywords: morphological processing, lexical strata, semantics, opacity

The Dutch low-frequency morphologically complex word *branding*, 'surf, the rolling and splashing of the waves' (7 occurrences per million), consists of two high-frequency constituents, *brand*, 'fire, to burn' (111 occurrences per million), and the nominalizing suffix *-ing* (13330 occurrences per million).[1] Semantically opaque words such as *branding* pose an interesting challenge for dual route models of morphological processing in word recognition that allow complex words to be recognized by means of both a direct route and a parsing route (Baayen, Dijkstra, & Schreuder, 1997; Burani & Laudanna, 1992; Frauenfelder & Schreuder, 1992; Laudanna & Burani, 1995; Schreuder & Baayen, 1995).

Consider the question how the meaning of opaque complex words such as *branding* might be accessed. The simplest solution is to assume that their full-form access representations provide pointers to their stored meanings (which are unpredictable by rule) and that the parsing route does not play a role (see, e.g., Frauenfelder and Schreuder, 1992). This solution would be consistent with the results of Marslen-Wilson,

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Tyler, Waksler, and Older (1994), who, in a cross-modal priming task, observed effects of morphological structure for semantically transparent words only. Thus, it would seem that constituent structure is irrelevant for opaque complex words.

However, although in general opaque complex words tend to have high frequencies of use, guaranteeing efficient direct access, it is not self-evident for low-frequency words such as *branding* that the direct route is fast enough to complete lexical access before the parsing route. Complex words with low full-form frequencies and high constituent frequencies are optimal candidates for being effectively processed on the basis of their constituents (Burani & Laudanna, 1992; Baayen, Dijkstra, & Schreuder, 1997). This holds for transparent complex words and opaque complex words alike. If the parsing route applies autonomously to its input irrespective of semantic transparency, as expected in a modular bottom-up architecture, then the parsing route may be expected to lead to the activation of the morphological constituents of *branding*, and hence to the activation of the semantic and syntactic representations of these constituents. Given a large frequency imbalance between the full-form frequency of the complex word as a whole on the one hand, and the frequencies of its constituents on the other, in favor of the latter, parallel dual route models predict that the transparent, unintended, reading ('burning' for *branding*) would become available before the opaque, intended, reading ('surf' for *branding*). The challenge for parallel dual route models is to ascertain empirically whether their predictions for low-frequency opaque complex words find empirical support.

This study is an attempt to come to grips with the role of the parsing route for low-frequency opaque words with high-frequency constituents by asking the following questions. First, does identification of the constituents of opaque complex words take place? This question is addressed in Experiment 1. Second, does activation of the corresponding semantic representations of these constituents take place? And if so, in which order do the meanings of the constituents and the opaque meaning of the complex word as a whole become available? These issues are addressed in Experiment 2. Finally, Experiment 3 considers the question whether the observed effects are crucially dependent on the presence of productive morphology.

Experiment 1

Experiment 1 investigates the role of semantic transparency for the processing of low-frequency morphologically complex words by orthogonally contrasting Semantic Transparency (opaque versus transparent) with Constituent Frequency (high versus low frequency of the base word). If the base word is identified in low-frequency complex words and plays a role in lexical processing, then we may expect that complex words with a high-frequency base word are responded to more quickly in visual lexical decision than comparable complex words with low-frequency base words. If semantic opacity effectively downplays the relevance of the constituents for lexical processing, as suggested by Frauenfelder and Schreuder (1992) and Schreuder and Baayen (1995), then the effect of constituent frequency should be small or absent for opaque complex words compared to transparent complex words. Conversely, if semantic transparency is in fact irrelevant so that constituent identification takes place for opaque and transparent complex words with a high-frequency base word alike, then opaque and transparent words should show a similar effect of constituent frequency.

Other studies on the role of constituent frequencies (Andrews, 1986; Burani & Caramazza, 1987; Colé, Beauvillain & Segui, 1989; Taft, 1979) have shown that lexical processing is indeed sensitive to Constituent Frequency. However, these studies have not addressed the role of semantic transparency in relation to the constituent frequency effect. There are several ways in which the frequency of a constituent such as *brand* in *branding* can be assessed. First, we may consider the frequency of the wordform *brand* itself in isolation. We will refer to this frequency count as the Base WordForm Frequency. Second, there is evidence suggesting that the frequencies of inflected variants of a given base form accumulate with the Base WordForm Frequency (Baayen, Dijkstra, & Schreuder, 1997; Baayen, Burani, & Schreuder, 1997). We will refer to this cumulated count as the Base Lemma Frequency. Finally, a word such as *brand* also occurs in many derived words and compounds (e.g., *brandbaar*, 'burn-able', 'inflammable'). The summed frequencies of such derived words and compounds, excluding the Base Lemma Frequency itself, will be referred to as the (morphological) Family Frequency. Taft (1979) presents data suggesting that the Family Frequency also affects lexical processing. On the other hand, Schreuder and Baayen (1997) have observed that for monomorphemic Dutch nouns Family Frequency is irrelevant. By contrast, a type count of the number of different derived words and compounds in the morphological family of monomorphemic nouns, the (morphological) Family Size, was found to be a crucial co-determinant of response latencies in visual lexical decision.

For morphologically complex words, the respective roles of Family Size and Family Frequency have not yet been teased apart. Bertram, Baayen, and Schreuder (1999) report that a high family size of the base word of a complex word, henceforth the Base Family Size, may also speed up response latencies in visual lexical decision, depending on the kind of word formation involved. In their experiments the Base Family Size covaries with Base Family Frequency, however. In the present experiments, we therefore constructed our materials such that the contrast in Constituent Frequency reflects all three frequency contrasts at the same time: a contrast in Base Lemma Frequency, a contrast in Base Family Frequency, and a contrast in Base Family Size. A low Constituent Frequency thus denotes a low score on all three counts, and a high Constituent Frequency denotes a high score on all three counts. In this way, we maximalize our chances of observing an effect of Constituent Frequency.

Method

Participants Eighty participants, mostly undergraduates at Nijmegen University, were paid to participate in the experiment. All participants were native speakers of Dutch.

Materials We have selected our word materials from a low surface frequency range of 10 to 500 per 42 million word tokens, using the CELEX lexical database (Baayen, Piepenbrock, & Gulikers, 1995). Four sets of words were created, varying with respect to the design factors Transparency and Constituent Frequency. The set of opaque words contained fourteen words with a high constituent frequency (Base Lemma Frequency: 13198; Base Family Frequency: 13113; Base Family Size: 82) and fourteen words with a low constituent frequency (Base Lemma Frequency: 397; Base Family Frequency: 378; Base Family Size: 15). The set of transparent words likewise contained fourteen words with a high constituent frequency (Base Lemma Frequency: 8751; Base Family Frequency: 8887; Base Family Size: 115) and fourteen words with a low constituent frequency (Base Lemma Frequency: 536; Base Family Frequency: 351; Base Family Size: 15).

Appendix A lists our experimental materials. Each set of words contains two words with the suffix *-ing*, eight words with the suffix *-ig*, one with the suffix *-achtig*, two with the suffix *-er*, and one with the suffix *-lijk*, so that the sets are matched for the distributional properties of the affixes (see, e.g., Burani, Dovetto, Thornton, & Laudanna, 1997, for the relevance of distributional properties of affixes for lexical processing). For each target word, it lists the relevant frequency measures, as well as the English translation equivalents of the base word and the complex word as a whole. We have used the morphological properties of translation equivalents as an objective means to confirm that our opaque and transparent words differ substantially with respect to semantic compositionality. Transparent, compositional words will tend to translate into complex words which are likewise compositional on a morpheme by morpheme basis. For instance, Dutch *stof+ig* translates straightforwardly into English *dust+y* with full translation equivalence between base, affix, and full form, and full compositionality in both languages. Conversely, opaque complex words tend to have morphologically unrelated translation equivalents. For example, Dutch *brand+ing* is derived from the verb 'to burn', but has a translation equivalent in English the monomorphemic noun *surf*, morphologically unrelated to the English verb *burn*. Of course, the two languages occasionally use the same morphemes to express the same opaque meaning, which occurs in two instances in our opaque set (e.g., *kat+ig* and *cat+y* both denote an unpleasant character trait using the same animal as point of departure for the same idiomatic metaphorical extension). Generally, however, opaque complex words require morphologically unrelated translation equivalents. The general principle of compositional translation equivalence between related languages is clearly reflected in our materials. The pairs of translation equivalents for the base word and the complex word in the set of transparent words make use of the same English stem in 25 out of 28 pairs. For the opaque set, only 2 out of 28 pairs do so. These counts provide a strong objective indication that our two sets of words differ considerably with respect to semantic transparency.

Each participant was exposed to 14 target words, all of which were either opaque or transparent. Half of these words had a low constituent frequency, and half a high constituent frequency. Affix types were equally distributed over the two sets. In addition, 36 morphologically complex words with constituents that did not appear in the target words, as well as 150 monomorphemic words were added as filler materials. Orthographically legal nonwords corresponding to the words with respect to length and morphological constituency were constructed. Thus, the experiment contained 200 word trials and 200 nonword trials. The experiment was preceded by a practice session with 20 word trials and 20 nonword trials.

Procedure

Participants were tested in groups of three in individual noise-proof experimentation booths. They received standard lexical decision instructions. Each trial consisted of the presentation of a fixation mark (asterisk) in the middle of the screen during 500 ms, followed after 50 ms by the stimulus centered at the same position. Stimuli were presented on Nec Multisync color monitors in white upper-case 36 points Helvetica letters on a dark background. Stimuli remained on the screen for 1500 ms. Time-out occurred 2000 ms after stimulus onset. Three pauses were included, one of which directly followed the practice session. The total duration of the experiment was approximately 35 minutes.

Results

For each participant, the proportion of incorrect responses was calculated for all trials in the experiment. The data of two participants performing with an error score greater than 10 percent were discarded in the analyses. Four of our critical experimental words elicited error scores higher than 30 percent, and were also discarded. Table 1 summarizes the mean reaction times and error scores for the different experimental conditions using the remaining observations.

Table I. Mean reaction time by participant as a function of Transparency and Constituent Frequency (Experiment 1). Error percentages between parentheses.

	transparent	opaque
High Constituent Frequency	582 (6.0%)	584 (3.6%)
Low Constituent Frequency	608 (4.4%)	631 (8.8%)

By-item and by-participant analyses of variance were carried out on the reaction times with the two factors, Transparency and Constituent Frequency. Transparency was a between-subjects factor in the analysis by participants. No significant effect of Transparency was obtained ($F_1, F_2 < 1$). The effect of Constituent Frequency was significant both by participant and by item ($F_1(1,76) = 21.7, p < .001, \mathrm{MSE} = 2396.7$, $F_2(1,48) = 6.8, p < .01, \mathrm{MSE} = 2549.5$). The interaction of Transparency and Constituent Frequency was not significant ($F_1(1,76) = 1.9, p < .2, \mathrm{MSE} = 2396.7, F_2 < 1$). The error scores suggest a slight speed-accuracy trade-off in the Transparent condition. However, the difference between the two conditions (1.6%) is not statistically reliable ($t(37) = .93, p > .3$).

Discussion

Experiment 1 addressed the question whether the base word constituent of opaque morphologically complex words plays a role during visual word recognition. For the transparent words, we observe the expected pattern of results. Transparent words with a high Constituent Frequency are processed faster than words with a low Constituent Frequency while matched on Surface Frequency. This suggests that the morphological constituents are identified. This possibility is supported by post-hoc by-item correlational analyses, which reveal significant correlations of RT and the (logarithmically transformed) frequency measures related to the base word, and no correlation with the (logarithmically transformed) frequency of the word as a whole (Surface Frequency $r = -.28, t2(24) = -1.41, p > .15$, Base Frequency: $r = -.54, t2(24) = -3.16, p < .01$, Base Family Size: $r = -.59, t2(24) = -3.56, p < .01$, Base Family Frequency: $r = -.42, t2(24) = -2.28, p < .05$). Our hypothesis is that these low-frequency transparent words are primarily processed on the basis of their constituents.

To our surprise, the effect of Constituent Frequency for opaque words is at least as large as that for transparent words. After all, processing of opaque words is generally assumed to proceed on the basis of full-form representations, since rules cannot, by definition, provide access to irregular, opaque meanings. However, post-hoc correlation analyses show neither reliable correlations of RT with Surface Frequency, nor any such correlation with Base Lemma Frequency, Base Family size, or Base Family Frequency (Surface Frequency: $r = -.06, t2 < 1$; Base Frequency: $r = -.21, t2(24) = -1.06, p > .25$; Base Family Size: $r = -.28, t2(24) = -1.44, p > .15$; Base Family Frequency: $r = -.17, t2(24) < 1$). Apparently, Constituent Frequency has some role to play, as shown by the factorial results, while at the same time the correlation analyses suggest that some additional process may also be involved that superimposes extra variability, masking the correlations between Constituent Frequency and the response latencies on an item by item basis. We will return to this issue in the discussion of Experiment 2.

Assuming that the constituents of our low-frequency opaque words are identified, we now turn to consider the question whether the base word of opaque complex words is only identified without activation of its semantics, or whether its semantics become available together with the idiosyncratic semantics of the complex word itself. Of special interest is the relative time course of the possible activation of these two distinct meanings. This issue is addressed in Experiment 2.

Experiment 2

To investigate whether the semantics of the base word in an opaque complex word are activated, we made use of a semantic priming design. We used opaque complex words (consiting of a formally completely regular combination of an existing stem and an affix subcategorized for that stem) with a low Full-Form Frequency and a high Constituent Frequency as critical primes. For each of these primes, two targets were chosen, one transparently related to the meaning of the base, and one related to the idiomatic opaque meaning of the derived word. In addition, monomorphemic control primes were selected that were unrelated to both kinds of target words. Thus we have the following four conditions, exemplified for the critical prime *branding*, derived from the verbal base *brand*, 'fire, burn'.

Condition	Prime	Target
base-related	branding ('surf')	vuur ('fire')
full-form-related	branding ('surf')	zee ('sea')
base-related control	schuchter ('shy')	vuur ('fire')
full-form-related control	schuchter ('shy')	zee ('sea')

To investigate the time course of the activation of the opaque and transparent meanings, we presented the prime-target pairs with two different stimulus onset asynchronies (SOA).

Method

Participants One hundred nineteen participants, mostly undergraduates at Nijmegen University, were paid to participate in the experiment: 58 for SOA 150, and 61 for SOA 500. All were native speakers of Dutch.

Materials
We selected seventeen critical primes and the corresponding control primes and target words. These words are listed in Appendix B.1, together with the frequency characteristics of the critical primes and the English translation equivalents of the base and the full form. For all prime-target pairs, semantic relatedness ratings were obtained (see Appendix B.2). Only one condition, the full-form-related condition, received a high relatedness rating, indicating that the forty participants in the rating experiment were aware of the idiomatic meaning of primes such as *branding*. In addition, familiarity ratings were obtained for all primes and targets (see Appendix B.2). Although the primes

had a low surface frequency, they were rated as reasonably familiar (approximately 5 on a seven-point scale), indicating that they are not from too low a frequency range. Despite a difference in their Full-Form frequency, the two kinds of targets were nevertheless rated as roughly equally familiar.

We constructed four experimental lists, selecting one condition from each set and rotating over conditions, so that each list contained exactly 17 different items. Three conditions were represented by four items, and one condition by five items. The condition with five items was rotated across the lists. For each prime-target pair, a word-nonword pair was constructed. In addition to these 34 word and nonword pairs, 17 word-word pairs and 17 word-nonword pairs were selected as filler materials. None of the word-word fillers were semantically related in any way. Finally, 10 word-word and 10 word-nonword practice items were created. The total number of items in the experiment was 88.

Procedure Participants were tested in groups of four in individual noise-proof experimentation booths. They received lexical decision instructions which made explicit that they had to respond to the second stimulus in each trial. Each trial consisted of the presentation of a fixation mark (asterisk) in the middle of the screen during 500 ms, followed after 50 ms by the prime centered at the same position. After 50 ms, or after 400 ms, the prime disappeared, and 100 ms later the target was displayed centered at the same position. The target remained on the screen for 1500 ms. Time-out occurred 2000 ms after stimulus onset. Stimuli were presented on Nec Multisync color monitors in white upper-case 36 points Helvetica letters on a dark background. The total duration of the experiment was approximately 15 minutes.

Results and Discussion

The data of participants with error scores exceeding 10% were removed from the analysis (two for SOA 150, and two for SOA 500). For each SOA, we carried out one-tailed t-tests across participants and across items to ascertain whether the difference between the prime and control conditions was reliable. Table 2 summarizes our results. For SOA 150, a significant priming effect was obtained for the Full-Form related condition ($t1(56) = 2.6, p = .006$, $t2(16) = 2.8, p = .007$). No priming effect was observed for the Base-related condition (both t-values less than 1). For SOA 500, the priming effect for the Full-Form related condition was marginally significant by participants ($t1(59) = 1.5, p = .065$) and significant by items ($t2(16) = 2.4, p = .015$). At this

SOA, the effect of Base-related priming was significant both by participants and by items ($t1(59) = 2.2, p = .017$, $t2(16) = 2.0, p = .034$). Further inspection of our items revealed two outlier items with mean difference scores greater than the cell mean plus two standard deviations in the opposite direction expected for priming. One such item occurred in the Base-related condition for SOA 150, and the other item occurred again in the Base-related condition but now at SOA 500. T-tests for these two conditions after removal of these two outliers resulted in a non-significant effect for the Base-related condition in the short SOA ($t2(15) = -1.64, p = 0.12$) and a solid effect for the Base-related condition in the long SOA ($t2(15) = -3.39, p = 0.004$). Using Bonferroni's inequality and focusing on the item-analyses, we conclude that the priming effect is reliable at SOA 150 for the Full-Form related condition only and that it is reliable at SOA 500 for the Base-related condition only (all p-values $< 0.05/4.0 = 0.0125$).

Table II. Mean reaction time by participant to morphologically complex opaque derived words as a function of Stimulus Onset Asynchrony, Relatedness (related versus unrelated) and Transparency (related to Base, transparent; related to Full Form, opaque) in Experiment 2. Error proportions between parentheses.

	stimulus onset asynchrony			
	150		500	
control	518	(.01)	538	(.02)
base-related	511	(.01)	512	(.02)
control	542	(.03)	528	(.06)
full-form related	515	(.03)	516	(.02)

Apparently, the opaque meaning is already activated at the short SOA of 150 ms. At the longer SOA of 500 ms, there appears to be some activation left, but the t-tests do not suggest that this late activation is completely reliable. Conversely, the meaning of the base is not activated at all for the short SOA, while it is clearly activated at the long SOA. [2]

We can now answer our original questions concerning semantic activation and its relative time course for base word and full form. Experiment 1 revealed that a high Constituent Frequency influences response latencies to both opaque and transparent complex words. The factorial results of Experiment 1 suggest that, apparently, the constituents of low-frequency complex words are at the very least identified irrespective of their transparency. Experiment 2 shows that the constituents of opaque words are not only identified, but that their meaning becomes activated as well.

With respect to the time course of semantic activation, we observe that, surprisingly, the opaque meaning of the full form of a morphologically complex word is activated long before the meaning of its base, despite the high Constituent Frequency of the base word and the low Full-Form Frequency of the complex word itself. The observed pattern is the exact opposite of what might be expected on the basis of the frequency relations between full form and base. It is also unexpected in the light of the absence of any indication of a full-form frequency effect in Experiment 1.

On the other hand, the present results are similar to those obtained for monomorphemic homonyms. For words such as *bank*, the dominant reading becomes available earlier in time than the non-dominant reading. In our present data, we likewise observe that the dominant meaning, the one related to the full form, becomes available long before the non-dominant reading, a reading that is a possible reading morphologically but that is not used in Dutch at all. What remains remarkable is that the non-dominant reading becomes activated at all, given that speakers of Dutch never use the word in that sense.

How can we explain this crossover pattern of activation over time of the two meanings? One possibility is to assume that the direct route would have such an advantage over the morphological parsing route that access to the idiosyncratic meaning would be completed long before the parsing route completes activation of the meaning of the base word. Under this assumption, segmenting the input into base word and affix would be a very time-costly operation. Whereas the full form would activate the opaque meaning within 150 ms, parsing the input into base word and affix would require more time.

This explanation, however, is incompatible with the absence ($r = 0.06$) of a correlation of Surface Frequency of the opaque words and the response latencies in Experiment 1, and it is also at odds with a series of studies modeling experimental results. The computational models suggest that the segmentation time, the time required for parsing the input into its constituents, is much shorter than 100 ms. For Dutch verb plurals, segmentation appears to be completed within 20 ms (Baayen, Dijkstra, en Schreuder, 1997), and segmentation times for Italian noun plurals appear to be of the same order of magnitude (Baayen, Burani, and Schreuder, 1997). These findings suggest that segmentation by itself is not time-costly at all.

If *branding* is rapidly segmented into *brand* and *ing*, why then does it take such a long time for *brand* to activate its meaning ('fire')? And why do the post-hoc analyses of Experiment 1 not reveal any reliable correlations between our measures of Constituent Frequency and the response latencies for opaque words, in contrast to transparent words? If the base word is indeed rapidly segmented out, how then is it possible that the meaning of the full form is activated more quickly than the meaning of the base, initially biasing the competition process completely to the advantage of the opaque meaning? Is this due to the high speed of the direct route? Given the low frequency of the full form and the high constituent frequencies, the likelihood that the direct route is the first to complete lexical access is small, however. How can we resolve this paradox?

The solution that we would like to offer here hinges on the concept of integration nodes introduced by Schreuder (1990) for the processing of particle verbs in Dutch. Particle verbs such as *op-vallen* (up-fall, 'to attract attention') and *af-vallen* (off-fall, 'to loose weight') have highly idiomatic meanings that pose a special problem for lexical processing as the particle (*op, af*) can occur separated from the base: *zij valt niet genoeg af*, 'she doesn't loose enough weight'. To allow the correct but unpredictable meaning 'to loose weight' to be accessed on the basis of the separated constituents *valt*, 'falls' and *af*, 'off', Schreuder (1990) introduced the notion of the integration node. Integration nodes require input from two constituents (e.g., *valt* and *af*) to reach threshold activation level. Once threshold has been reached, the integration node will activate the idiosyncratic meaning of *afvallen*, 'to loose weight', and at the same time inhibit the regular meanings of these constituents ('fall' and 'off'). Thus, the integration node serves the purpose of redirecting the activation of the constituents to the correct opaque meaning, effectively pre-empting rule-based semantic composition.[3]

Within the framework developed by Schreuder & Baayen (1995), we can understand the present results along very similar lines. Figure 1 shows an outline of the representations and the connections between representations that might be involved in the processing of opaque words such as *branding*. At the layer of access representations we find orthographic units for the stem *brand* and the suffix *-ing*, as well as for the full form *branding*. Upon encountering a low-frequency word such as *branding*, these three access representations become active, the access representation for the full form slowly, the access representations of the high-frequency constituents *brand* and *ing* quickly.

The access representations activate their corresponding lemma nodes, the middle layer in Figure 1. These lemma nodes mediate between the access representations and the semantic and syntactic representations

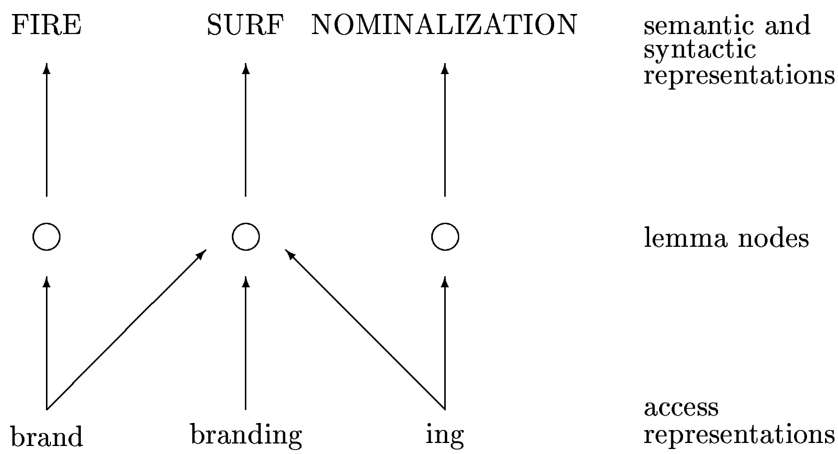

Figure 1. Representations for *branding* in a spreading activation model of morphological processing.

in the central lexicon, the top layer in Figure 1. These central representations have been glossed by the dummy markers 'SURF', 'FIRE', and 'ING'. For fully transparent derived words such as *snelheid*, 'quickness', i.e., 'speed', there are no links between the access representations of the constituents and the lemma representation of the full form. In the case of words such as *branding*, however, such links are posited. Their functionality is similar to the functionality of the links between access representations and the integration nodes of Schreuder (1990). In fact, the lemma node of *branding* has the same function as the integration node proposed in this study. Thus, upon activation of *brand* and *-ing*, the lemma node of *branding* receives sufficient activation to access the opaque meaning 'surf'. Because the high-frequency suffix *-ing* reaches threshold first, the lemma node of *branding* is already pre-activated. Consequently, when *brand* reaches threshold, the lemma node for *branding* can reach threshold before the lemma node of *brand* itself. Hence, the meaning 'surf' becomes available before the meaning 'fire'.

We suspect that the absence of reliable correlations of our measures of Constituent Frequency with the response latencies for the opaque words in Experiment 1 is due to the pre-activation of the lemma nodes of the full forms by the various different affixes used in that experiment. Each affix has its own resting activation level proportional to its frequency of use and its distributional properties (Laudanna & Burani, 1995). Consequently, the amount of pre-activation of the lemma nodes of the opaque full forms differs for words with different affixes. Hence the contribution of the base to the activation of the lemma node of the opaque full form is no longer a simple function of the frequency of the base. Pre-activation introduces additional variability, masking the way in which item-specific frequency-determined resting activation levels influence lexical processing within the high and low Constituent Frequency sets of target words. As a result, a reliable correlation between constituent frequency and response latencies can no longer be observed, although the correlation still is in the predicted direction.

Experiments 1 and 2 show that base words in complex words play a role in morphological processing independently of their semantic transparency. All complex words studied in these experiments contain productive affixes that attach to independently occurring words. In the next Experiment, we investigate whether opaque complex words with unproductive affixes and bound stems that do not occur in isolation also reveal a role for the bound base word in lexical processing.

Experiment 3

In Experiment 3 we compare complex words from the Germanic and Romance strata of the Dutch lexicon. The larger part of the Dutch lexicon falls into the Germanic stratum, and it is here that most productive word formation rules are found. These word formation rules take as their input freely occurring words to yield new words. For instance, the suffix *-baar* ('-able') attaches to the verb form *brand* ('burn') to yield *brandbaar* ('inflammable').

The Romance stratum contains a range of words historically borrowed from French, Latin, and to some extent Greek. Word formation in this stratum is not based on freely occurring words, but on bound stems, forms that do not occur in isolation. For instance, *dictie*, 'diction', can be analyzed into the bound stem *dict-* and the suffix *-ie*. Most word formation patterns in this stratum, which in Dutch is much more restricted than in English, are not productive, due to the absence of regular form-meaning correspondences (Van Marle, 1985). The majority of the complex words in the Romance stratum is semantically opaque.

Nevertheless, complex words in the Romance stratum vary on the dimensions of Base Family Size and Base Family Frequency, defined on the basis of their etymologically determinable bound stems. Hence, just as in Experiment 1, we proceed to contrast Constituent Frequency, but now for the Romance stratum as well as for the Germanic stratum. Note that Constituent Frequency consists of the Base Lemma Frequency, Base Family Size, and Base Family Frequency for the Germanic Stratum, and of Base Family Size and Base Family Frequency only for the Romance Stratum — the Romance stratum makes use of bound stems that do not occur in isolation. Also note that the difference in Stratum is correlated with a difference in register and age of acquisition. Words from the Romance stratum occur primarily in formal styles (officialese, scientific prose), and they are generally acquired after primary school.

The overall properties of Germanic and Romance words suggest that Stratum will emerge as a main effect with Romance words being responded to somewhat more slowly. Our interest, however, is not in this main effect, which can be traced to a great many different possible sources. The focus of our attention is the behavior of Constituent Frequency across the two strata. What we expect to find is that the effect of Constituent Frequency is larger for the Germanic stratum than for the Romance stratum.

It is important to note that our predictions are specific for Dutch and other Germanic languages such as German, Norwegian, Swedish, and Danish, which, unlike English, make only very restricted use of Romance morphology. Dutch morphology is word-based, in the sense that freely occurring forms are input to morphological rules. The learned words from the Romance stratum are exceptional, and the likelihood that their etymological structure has psychological relevance is small for the average speaker of Dutch. We do not claim that bound stems as such cannot be active processing units. In languages such as French and Italian, productive morphology is based on bound stems, and not on free forms as in Dutch. We have opted for studying bound stems in Dutch not because they are bound, but because they are part of the unproductive part of the Dutch lexicon.

Method

Participants Fifty-five participants, mostly undergraduates at Nijmegen University, were paid to participate in the experiment. All were native speakers of Dutch.

Materials We have selected our word materials from the low Surface Frequency range of approximately 25 on 42 million occurrences, using the CELEX lexical database. This allowed us to make a maximal contrast between Surface and Constituent Frequency, as it is especially in the lower frequency ranges that we expect parsing to be effective, and hence for Constituent Frequency to play a role.

We have constructed two sets of materials, one containing only words from the native or Germanic stratum of the Dutch lexicon, the other containing only words with a Romance origin. The words from the Germanic stratum were fully transparent complex words with undisputed Germanic affixes. The words from the Romance stratum were opaque and contained unproductive formatives that on etymological grounds can be argued to be affixes. Within each set, we contrasted two further sets that differed as maximally as possible with respect to Constituent Frequency.

For the Germanic stratum, the contrast in Constituent Frequency is realized in terms of Base Family Frequency, Base Family Size, and Base Lemma Frequency. For the Romance stratum, this contrast is carried only by Base Family Size and Base Family Frequency, as the base words of Romance complex words are bound forms with no independent frequency of their own. For each of the four cells of our orthogonal design (Constituent Frequency x Stratum, using a complete within-subject design), we obtained a total of 14 words. The contrasts in Constituent Frequency in the Germanic and Romance strata were of the same order of magnitude, as shown in Appendix C. The overall ratio of string familiarity, evaluated in terms of the sum of Surface Frequency, Base Family Frequency, and Base Lemma Frequency, was similarly balanced between the Constituent Frequency conditions (9930/928 = 10.7 for Romance, 15996/1538 = 10.4 for Germanic). Appendix C lists our materials, their frequency characteristics, and the English translation equivalents of the constituents and the full form. Note that 3 out of 28 Romance words have English translation equivalents sharing the same Romance root. This contrasts with the Germanic words, for which 27 out of 28 cases translate with the same stem. This shows that the Romance and Germanic words differ substantially with respect to their semantic transparency.

In addition to the critical target words, we included 114 filler words in the experiment. This set of filler words contained both monomorphemic and morphologically complex words from the medium frequency ranges. The experiment was preceded by a practice session with 30 low and high frequency Germanic and Romance words.

For each word in our experiment, an orthographically and phonotactically legal pseudoword was constructed of approximately the same length and of similar morphological complexity. Thus, we used pseudowords resembling Romance words (e.g., *confreus*, compare with existing words such as *confronteer*, ‘confront’, and *affreus* ‘awful’), and pseudowords resembling Germanic complex words (e.g., *druinlijk*, consisting of a pseudostem and the Dutch Germanic suffix *-lijk*, ‘-like’).

The total number of trials in the experiment including the practice trials was four hundred.

Procedure The procedure was identical to that of Experiment 1. The total duration of the experiment was approximately 35 minutes.

Results

For each participant, the proportion of incorrect responses and missing data was calculated over all word trials in the experiment. Overall, the participants performed the task accurately, with less than 10% errors. All observations were therefore used to calculate item and participant mean reaction times and error scores for the different conditions. It turned out that several experimental words elicited high numbers of errors. We removed 11 Romance words and four Germanic words that showed error rates exceeding 30% from the data set (see Appendix C for details).

Removal of these items did not affect the matching for Surface Frequency, nor were the ratios of string familiarity between the high and low Constituent Frequency conditions effected substantially (Romance: $8419/714 = 11.8$; Germanic: $16104/1636 = 9.8$). Table 3 shows the mean reaction times and error scores for the different experimental conditions using the remaining data points.

Table III. Mean reaction time by participant as a function of Stratum and Constituent Frequency (Experiment 3). Error percentages between parentheses.

	Germanic	Romance
High Constituent Frequency	610 (6.6%)	665 (20.0%)
Low Constituent Frequency	641 (12.2%)	637 (14.1%)

By-participant and by-item analyses of variance were carried out on the response latencies. No significant effect of Constituent Frequency was observed ($F_1(1,54) < 1$, $F_2(1,37) < 1$). The effect of Stratum was significant by participant and marginally significant by items ($F_1(1,54) = 13.3$, $p < .001$, MSE = 2543; $F_2(1,37) = 2.8$, $p < .10$, MSE = 2201). The interaction of Stratum and Constituent

Frequency was significant by participants ($F_1(1,54) = 16.0$, $p < .001$, MSE = 3326) and marginally significant by items ($F_2(1,37) = 3.6$, $p < .07$, MSE = 2201). The error analysis revealed a similar pattern of results.

The difference of 28 milliseconds (in the wrong direction for a frequency effect) between the Romance high (665 ms) and low (637 ms) Constituent frequency conditions was significant by participants but did not receive any support in the by-items analysis ($t_1(54) = 2.1, p < 0.05; t_2(15) < 1$, two-tailed t-tests). By contrast, the difference of 31 milliseconds between the Germanic high (610 ms) and low (641 ms) Constituent Frequency conditions was significant in the predicted direction both by participants and by items ($t_1(54) = -4.5, p < .001; t_2(22) = -2.0, p < .03$, one-tailed t-tests).

Post-hoc analyses of the correlations of our measures of Constituent Frequency with the response latencies for the Germanic and Romance subsets of words revealed the following pattern. For the Romance words, the only significant correlation concerned Surface Frequency ($r = -0.53$, $t(15) = -2.4, p < .03$). For Base Family Frequency and Base Family Size, the correlations were less than .06 ($t < 1$ in both cases). For our Germanic words, by contrast, Base Lemma Frequency and Base Family Frequency revealed significant correlations (Base Lemma Frequency: $r = -.41, t(22) = -2.1, p < .05$; Base Family Frequency: $r = -.48, t(22) = -2.6, p < .02$) while Surface Frequency did not reveal a significant correlation ($r = -.31, t(22) = -1.5, p < .15$). Base Family Size also did not reveal a significant effect ($r = -.30, t(22) = -1.5, p < .15$).

We further computed the orthographic string familiarity of the affixes in the Germanic and Romance cells of the experimental design, restricting ourselves to the words included in the above analyses, to make sure that our results are not driven by the orthographic form properties of our target words. For the Germanic affixes, the affixal string familiarity (the summed frequencies of all words in the CELEX lexical database containing the orthographic affix string) in logarithmic units was 11.12 in the High Constituent Frequency condition, and 10.26 in the corresponding Low condition. (Note that the log affixal string familiarity is much higher than that of the base: 9.22 (log 10169) in the High and 7.48 (log 890) in the Low Constituent Frequency condition.) Log affixal string familiarity did not reveal any correlation with the response latencies ($p > .3$). For the Romance words in this experiment, log affixal string familiarity was 12.36 for the High Constituent Frequency condition and 12.63 for the Low Constituent Frequency Condition. (As before, the string familiarity of the base words is lower, 9.03 (log 8389) for the High and 6.52 (log 683) for the Low Constituent

Frequency condition.) Again, log affixal string familiarity did not reveal any reliable correlation with the response latencies ($p > .7$).

Discussion

The question we have addressed by means of Experiment 3 is whether morphological productivity is a necessary condition for the Constituent Frequency effect as observed in Experiment 1. We have addressed this question by comparing the effect of Constituent Frequency for the Romance and Germanic strata. For the Germanic stratum, we observe the expected effect of Constituent Frequency: Words with a high Constituent Frequency are processed faster than words with a low Constituent Frequency. By contrast, Constituent Frequency did not reveal any effect for the Romance stratum. We conclude that indeed full productivity is required for the effect of Constituent Frequency to emerge.

The orthographic string familiarity of the affixes in this experiment did not reveal any significant correlation with the response latencies, not for the Germanic words nor for the Romance words. This is in line with the predictions of a parallel dual route model for morphological processing. Whenever the full-form route wins the race, the constituents, their frequencies, and the time they need to reach threshold activation level do not determine the response latencies. In this case, response latencies will correlate with the frequencies of the full forms. When the parsing route wins the race, a response can only be executed after both constituents have reached threshold activation level. Given the much higher frequencies of the affixes in our experiment compared to the frequencies of the base words, the affixes will on average reach threshold activation level before the base words. Hence, response latencies for items recognized via the parsing route will correlate with the frequency of the base word, and not with that of the affix. Irrespective of which route wins the race, differences in affixal string familiarity are irrelevant to the pattern of results in the response latencies. We understand the results of the present experiment as indicating that the Romance words are recognized via the direct route only, while for the Germanic words the parsing route is predominantly used.

The results of Experiment 3 seem to contradict the results reported by Bergman, Hudson, and Eling (1988). In their Experiment 3, they compared Romance prefixed words with Romance monomorphemic words in a lexical decision task. They found that the prefixed words required longer response latencies than their monomorphemic controls. This, they argued, is evidence for obligatory prefix stripping for their

Romance prefixed words. Apart from some theoretical and statistical shortcomings of any theory of obligatory prefix stripping (see Schreuder and Baayen, 1994), we find the conclusion reached by Bergman et al. (1988) counterintuitive. Why would morphological processing take place for words the form and meaning of which are often completely unpredictable, such as *recept*, 'recipe' and *decreet*, 'decree'?

Inspection of the materials listed in Bergman (1988, pp. 207–208), the doctoral thesis on which the paper by Bergman et al. (1988) is based, suggests that there is a confound in their experiment. Their critical and control groups differed substantially with respect to the abstractness or concreteness of the words they used. For both groups, we counted the number of words denoting a picturable, concrete, physical object. For instance, *citroen*, 'lemon', and *horloge*, 'watch', were classified as concrete, while we classified *comfort*, 'comfort', and *illusie*, 'illusion' as abstract. It turned out that for their complex words, three out of 24 words were concrete. Conversely, 16 out of 24 words in the control set denoted concrete objects ($\chi^2(1) = 12.5, p < .001$). This strongly suggests that the difference in response latencies between the prefixed and control sets is due to a difference in concreteness (see, e.g., James, 1975).

Our conclusion that no morphological processing is involved for the Romance words in our Experiment 3 nor in any of the Romance words in Experiment 3 of Bergman et al. (1988) does not imply that no morphological processing can be involved for the complete nonnative stratum of the Dutch lexicon. As we have argued elsewhere (Schreuder and Baayen, 1995), morphological processing depends crucially on factors such as semantic and phonological transparency, frequency, productivity, affixal homonymy, and the extent of pseudo-affixation. The Romance materials in Experiment 3 are phonologically highly irregular and unpredictable, and semantically they are also quite opaque. This is characteristic for the Romance stratum as a whole, although there are some pockets of regularity where the parsing route might have some role to play (e.g., the suffix *-atie*, comparable to English *-ation*, which attaches to Romance verbs with the verbal suffix *-eer*). What Experiment 3 shows is that in the absence of morphological productivity a high Constituent Frequency by itself is not sufficient to give rise to effects of morphology in lexical processing.

General Discussion

We have addressed the question how low-frequency opaque complex words with high-frequency constituents are processed. Are the constituents of semantically opaque complex words identified just as for transparent words? If so, is this effect a genuine morphological effect, or does it arise irrespective of morphological productivity? If morphological decomposition is involved, how then might the unpredictable meanings of opaque complex words be accessed?

Experiment 1 contrasted low-frequency complex words with respect to their Constituent Frequency. Words with a high Constituent Frequency (i.e., with a high Base Lemma Frequency, a high Base Family size, and a high Base Family Frequency) were found to elicit shorter response latencies in visual lexical decision than words with a low Constituent Frequency. Surprisingly, this effect was equally large for opaque and transparent words. Interestingly, the opaque words did not show reliable correlations of our measures of Constituent Frequency with the response latencies, in contrast to the transparent words. At the same time, the opaque words also did not reveal any correlation of Surface Frequency with the response latencies.

Experiment 2 addressed the question whether the constituents of opaque words, which are apparently identified, also activate their meanings, and if so, in what order the meaning of the base word and the opaque meaning of the complex word become available. A semantic priming experiment with opaque complex words as primes revealed that both the usual opaque meaning as well as the meaning of the base become available. Surprisingly, despite the low surface frequency of the complex word itself, and despite the absence of a Surface Frequency effect in the correlations of Experiment 1, the first meaning to become active is the opaque one. Conversely, the meaning of the base becomes available relatively late, only after the activation of the opaque meaning has already entered decay. We have interpreted these results by adding an integration mechanism to the lemma nodes of the activation model proposed by Schreuder & Baayen (1995). The functionality of this integration mechanism is to redirect activation to idiosyncratic meanings on the basis of activated constituents when the direct route fails to do so efficiently.

In the case of particle verbs, for which the integration mechanism was first proposed (Schreuder, 1990), the direct route fails due to the separation of the particle from its base by intervening materials. In the present case of low-frequency opaque complex words with high-frequency constituents, the direct route fails due to the frequency imbalance. In both cases, an integration mechanism allows efficient access to idiosyncratic meanings. The integration mechanism depends on the output of the segmentation process which leads to the activation of the access representations of the constituents. Since high-frequency constituents are activated more quickly than low-frequency constituents, we observe an effect of Constituent Frequency in Experiment 1 irrespective of whether complex words are semantically transparent. However, since integration is involved in the processing of opaque words, extra variability is introduced, leading to the absence of reliable correlations of our measures for Constituent Frequency with the response latencies for the opaque words in Experiment 1.

Experiment 3 considered the possibility that the effect of constituent frequency observed in Experiments 1 and 2 might arise only for complex words with productive constituents. To this end, the effect of Constituent Frequency was examined for productive morphology in the Germanic stratum of Dutch and for unproductive morphology in the Romance stratum of Dutch. We found an effect of Constituent Frequency only for the productive morphology. This shows that morphological productivity is a necessary condition for the effect of Constituent Frequency.

We are not the first to call attention to effects of the morphological structure of opaque words in visual lexical processing. Bentin and Feldman (1990, see also Stolz & Feldman, 1995) observed repetition priming both at short and long repetition lags for morphologically but not semantically related words. Unfortunately, repetition priming is a task that does not allow the researcher to disentangle effects of morphological structure that occur during lexical access itself and effects due to shared morphological representations in the central lexicon that become available after completion of lexical access. Our experiments, suggest that the early stages of lexical processing already reveal effects of morphological structure for opaque words with productive constituents.

At first sight, our results contrast with those obtained by Zwitserlood (1994), Sandra (1990), and Marslen-Wilson, Tyler, Waksler, and Older (1994). Zwitserlood (1994) studied the role of semantic transparency in the processing of nominal compounds in Dutch. Using the same priming technique as in our Experiment 2 she observed no priming effect for target words semantically related to one of the constituents of opaque compounds. Zwitserlood concludes that the constituents of opaque compounds are not identified and do not activate their meaning. However, Zwitserlood used an SOA of 300 ms. We observed a solid priming effect at a later SOA of 500 ms. Our findings suggest that the SOA of 300 ms used by Zwitserlood is perhaps too small to allow effects of priming to become visible. In our interpretation, the meaning of the constituent is still inhibited by the meaning of the complex word as a whole.

Sandra (1990), using similar techniques for the study of nominal compounds, also observed no effect of priming on target words that are semantically related to one of the constituents of opaque compounds. As pointed out by Zwitserlood (1994), the specific experimental procedure used by Sandra resulted in SOAs of approximately one second.

Sandra also concludes that the constituents of opaque compounds do not play a role in lexical processing. We suspect that at this long SOA used by Sandra, the meanings of the constituents of opaque complex words have fully decayed. But at an SOA of 500 ms, we observe reliable effects of priming. Thus it appears that Zwitserlood and Sandra have studied possible effects of morphology for opaque complex words using SOAs that are either too short or too long. Clearly, a wider range of SOAs is required in further studies of opaque compounds.

Marslen-Wilson et al. (1994) studied transparent and opaque derived words using cross-modal priming. They observed effects of priming for transparent derived words with respect to their stems (e.g, *punishment – punish*) but not for opaque derived words (*casualty – casual*). Their conclusion is that morphological structure is irrelevant for the processing of opaque complex words (but see Burani, 1993). We suspect that also in the auditory modality the first meaning to become available is the meaning of the opaque derived word itself. When visual targets are presented at the offset of the auditory primes, the meaning of the base constituents might well not be available yet, just as in the visual modality at short SOAs. Of course, the temporal nature of auditory presentation of the prime might affect the extent to which the meaning of the base word is still available at word offset, i.e., after the suffix. Further experimental research with a broader range of SOAs is required to ascertain whether and when the meanings of the constituents of opaque words are activated in the auditory modality.

What our results indicate is that morphological structure has some role to play even for opaque complex words, contrary to our own expectations (Baayen, 1993; Frauenfelder & Schreuder, 1992; Schreuder & Baayen, 1995). In fact, the evidence presented here converges with other evidence that morphology is not a-priori irrelevant for opaque complex words. Schreuder, Grendel, Poulisse, and van der Voort (1990), using an intramodal visual short SOA partial priming technique, observed effects of morphological structure for particle verbs, irrespective of their semantic transparency. Particle verbs in Dutch (e.g., *aanval*, 'on-fall', i.e., 'attack') are compounds the constituents of which can also occur with intervening words depending on the syntactic context. Syntactic flexibility enforces morphological parsing for particle verbs, irrespective of whether they are semantically opaque or not.

Similarly, Fleischeuers (1997) observed for idiomatic adjective-noun combinations such as *red herring* activation of both the meanings of the constituents as well as the meaning of the idiomatic combination as a whole, using visual priming tasks. As in our Experiment 2, constituent meanings are activated that are irrelevant to the meaning of the combination of constituents as a whole. Moreover, the time course of semantic processing of idioms seems to follow a similar pattern as we have observed in Experiment 2: It has often been observed that the idiomatic meaning of idiomatic phrases becomes available either first or in parallel with the literal meaning (see, e.g., Schweigert & Moates, 1988, and Swinney & Cutler, 1977).

Summing up, the constituents of opaque complex words can play a role in lexical processing in language comprehension. The experiments reported here for the visual modality suggest that in the case full-form access representations have too low resting activation levels to allow the direct route to complete lexical access before the parsing route, the parsing route is indeed involved. The parsing route activates the constituents, after which the integration mechanism of the lemma nodes in the central lexicon takes over the task of activating the required opaque meanings. Our conclusion is that, paradoxically, opaque words reveal more about morphology than we had ever thought.

Notes

[1] The verb *branden*, 'to burn', and its nominalization *branding*, 'surf', originally derive from the Indo-Germanic root *bhere(u)-*, 'to move vehemently'. In the verb, this meaning aspect applies to the flames, in the noun, it applies to the waves. See De Vries & de Tollenaere, 1958.

[2] Note that these results cannot be attributed to backward priming, as backward priming effects in lexical decision tasks typically do not decrease with increasing SOA, as shown by Peterson & Simpson (1989).

[3] In other words, the integration mechanism is an implementation of the knowledge that the language user has of conditional probabilities. The probability that *vallen* means 'to fall' is high, but the conditional probabiltity that *vallen* means 'to fall' in the context of *af* is low.

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Appendix A

Opaque, high Constituent Frequency							
Word	RT	Fsurf	FBase	Vf	Nf	Base Meaning	Word Meaning
achterlijk	630	260	24378	151	21703	behind	retarded
beeldig	508	58	8362	155	20613	image	gorgeous
bondig	629	109	847	44	2373	federation	terse
branding	608	307	4679	123	5348	burn	surf
geestig	515	307	8375	76	5277	ghost	funny
hartig	511	58	8059	123	6906	heart	tasty
kattig	557	37	3054	35	439	cat	catty
klinker	571	160	8209	21	972	sound	vowel
mondig	501	82	9798	39	1819	mouth	mature
roerig	608	79	1499	22	3164	rudder	turbulent
statig	683	374	12305	130	5014	state	solemn
waarachtig	646	448	69252	117	101846	true	truly
zekering	666	16	24640	72	8781	sure	fuse
zuiger	540	39	1312	40	1666	suck	piston
Means	584	167	13198	82	13280		

Opaque, low Constituent Frequency							
drachtig	627	34	78	5	260	garb	with young
jachtig	565	72	1104	40	931	hunt	hectic
krampachtig	623	467	326	20	787	spasm	frenetic
kranig	646	115	629	18	289	tap	brave
mollig	588	308	116	3	327	mole	plump
morsig		(69)	(212)	(5)	(98)	spill	messy
scheutig		(25)	(346)	(4)	(139)	splash	lavish
schichtig	694	308	47	3	402	flash	nervous
schutting	536	229	95	16	799	lock	fence
slijter	618	18	310	15	768	wear	liquor merchant
stamper	663	40	581	7	258	stamp	pistil
stierlijk	641	23	545	10	161	bull	beastly
tering	692	58	697	34	1127	tar	consumption
vinnig	630	222	234	8	318	fin	caustic
Means	627	158	397	15	536		

Appendix A (continued)

Word	RT	Fsurf	FBase	Vf	Nf	Base Meaning	Word Meaning
Transparent, high Constituent Frequency							
bangig		(11)	(7921)	(9)	(420)	afraid	somewhat afraid
bloedig	510	336	5801	115	4418	blood	bloody
bouwer	571	145	4840	243	14939	build	builder
eindig	595	89	6599	12	10236	end	finite
hoekig	566	205	5059	54	2912	edge	with edges
houtig	582	20	2056	113	4795	wood	woody
meting	642	285	1918	69	12059	measure	measurement
puntig	588	245	8842	136	11768	point	pointed
roodachtig	639	162	7055	59	2474	red	reddish
stoffig	535	443	4422	138	6161	dust	dusty
trekking	557	45	22587	126	32984	draw	drawing
vaderlijk	571	278	24412	50	4475	father	fatherly
waterig	556	249	15497	282	5863	water	watery
werper	641	70	4882	51	4816	throw	thrower
Means	582	198	8767	111	9069		
Transparent, low Constituent Frequency							
ijverig	548	498	576	16	941	diligence	diligent
moerassig	638	86	481	14	162	swamp	swampy
nukkig	624	77	37	2	84	quirk	quirky
ridderlijk	615	45	565	22	336	knight	knightly
roeier	623	45	537	13	794	row	rower
romig	642	159	240	21	624	cream	creamy
schimmig	585	98	513	10	218	shadow	shadowy
splijting		(20)	(248)	(8)	(164)	split	splitting
splitsing	633	200	429	8	363	bifurcate	bifurcation
spookachtig	565	207	856	15	659	spook	spooky
venijnig	719	258	64	2	270	venom	venomous
vettig	546	374	1604	45	1002	fat	fatty
wollig	574	83	423	22	671	wool	woolly
zaaier	635	45	642	15	615	sow	sower
Means	612	167	536	16	518		

Materials for Experiment 1: RT: response latency; Fsurf: Surface Frequency, FBase: Base Lemma Frequency; Vf: Base Family Size; Nf: Base Family Frequency. Means per group after removal of error-prone items, the items listed without a mean RT.

Appendix B.1

Relatedness	Prime	Freq	Target	Freq	English Translation		
					Base	Word	Target
base	branding	307	vuur	4646	burn	surf	fire
derived	branding		zee	6056	burn	surf	sea
-	schuchter	316	vuur			timid	fire
-	schuchter		zee			timid	sea
base	kattig	37	poes	3054	cat	catty	pussy
derived	kattig		snibbig	49	cat	catty	snappish
-	krokant	21	poes			crusty	pussy
-	krokant		snibbig			crusty	snappish
base	beeldig	58	scherm	981	image	gorgeous	screen
derived	beeldig		mooi	15065	image	gorgeous	beautiful
-	secuur	79	scherm			secure	screen
-	secuur		mooi			secure	beautiful
base	hartig	58	bloed	5801	heart	tasty	blood
derived	hartig		zout	2121	heart	tasty	salt(y)
-	egaal	87	bloed			smooth	blood
-	egaal		zout			smooth	salt(y)

Appendix B.1 (continued)

Relatedness	Prime	Freq	Target	Freq	English Translation		
base	lijvig	69	lichaam	12378	body	corpulent	body
derived	lijvig		dik	6724	body	corpulent	fat
-	bruto	140	lichaam			gross	body
-	bruto		dik			gross	fat
base	potig	71	been	8098	paw	burly	leg
derived	potig		fors	805	paw	burly	sturdy
-	alert	134	been			alert	leg
-	alert		fors			alert	sturdy
base	roerig	79	boot	2835	rudder	turbulent	boat
derived	roerig		druk	13117	rudder	turbulent	busy
-	ultiem	93	boot			ultimate	boat
-	ultiem		druk			ultimate	busy
base	mondig	82	lip	4594	mouth	mature	lip
derived	mondig		weerbaar	92	mouth	mature	able-bodied
-	robuust	151	lip			robust	lip
-	robuust		weerbaar			robust	able-bodied
base	houterig	88	boom	5862	wood	stiff	tree
derived	houterig		stijf	1806	wood	stiff	stiff
-	accuraat	96	boom			accurate	tree
-	accuraat		stijf			accurate	stiff

Appendix B.1 (continued)

Relatedness	Prime	Freq	Target	Freq	English Translation		
					Base	Word	Target
base	beestachtig	104	dier	7990	beast	bestial	animal
derived	beestachtig		gruwelijk	657	beast	bestial	gruesome
-	plausibel	154	dier			plausible	animal
-	plausibel		gruwelijk			plausible	gruesome
base	bondig	109	club	956	federation	terse	club
derived	bondig		kort	14846	federation	terse	short
-	subliem	162	club			sublime	club
-	subliem		kort			sublime	short
base	achterlijk	260	voor	293908	behind	retarded	before
derived	achterlijk		gek	5822	behind	retarded	idiot
-	clandestien	238	voor			clandestine	before
-	clandestien		gek			clandestine	idiot
base	geestig	307	spook	856	ghost	funny	phantom
derived	geestig		leuk	4026	ghost	funny	funny
-	discreet	443	spook			discrete	phantom
-	discreet		leuk			discrete	funny
base	huiselijk	364	deur	15927	house	homely	door
derived	huiselijk		knus	157	house	homely	cozy
-	continue	355	deur			continuous	door
-	continue		knus			continuous	cozy
base	statig	374	land	18637	state	solemn	country
derived	statig		deftig	647	state	solemn	dignified
-	attent	383	land			attentive	country
-	attent		deftig			attentive	dignified
base	jarig	382	maand	9727	year	birthday	month
derived	jarig		feest	2606	year	birthday	feast
-	ijdel	310	maand			vane	month
-	ijdel		feest			vane	feast
base	gangbaar	584	hal	1278	corridor	valid	hall
derived	gangbaar		gewoon	13509	corridor	valid	normal
-	vitaal	493	hal			vital	hall
-	vitaal		gewoon			vital	normal

Materials for Experiment 2: primes, targets, and their Surface Frequencies.

Appendix B.2

Type	Example	Familiarity Rating	Frequency
prime	branding	5.2	191
target stem	vuur	6.9	21980
target derived	zee	6.4	7765
prime control	schuchter	4.5	215
stem	brand	6.5	9691

Mean familiarity ratings (7-point scale) and mean surface frequency for the materials of Experiment 2.

Condition	Example	Relatedness Rating
Stem-related	branding - vuur	2.36
Derived-related	branding - zee	6.09
Stem-related control	schuchter - vuur	1.15
Derived-related control	schuchter - zee	1.94

Mean relatedness ratings (7-point scale) for the materials of Experiment 2.

Appendix C

Romance, high Constituent Frequency						
Word	RT	Fsurf	Vf	Nf	English translations constituents	full form
ab+ject		(14)	(97)	(9802)	off+throw	despicable
ad+struct+ie		(24)	(142)	(8979)	to+build+ion	substantiation
af+fect	565	44	77	8453	to+grasp	affect
con+vent	636	36	27	5912	together+come	monastery
de+cept+ie	662	7	56	5288	off+take+ion	deception
de+duct+ie	663	53	66	13714	off+lead+ion	deduction
de+termin+ist	743	11	44	7209	off+border+ist	determinist
gener+iek	695	17	60	7210	generate+ic	generic
in+finit+ief	669	4	31	5516	un+finite+ish	infinitive
part+ikel		(20)	(214)	(20390)	depart+ie	particle
port+o	626	98	154	9924	carry+o	postage
re+vis+or		(46)	(140)	(11943)	re+see+or	corrector
su(s)+spect	718	4	80	12275	under+see	suspect
tra+verse		(8)	(17)	(12011)	across+turn	arcade
Means	664	30	66	8389		

Romance, low Constituent Frequency						
al+lus+ie		(26)	(14)	(1608)	to+play+ion	allusion
cant+ate		(25)	(6)	(40)	sing+IMP	cantata
de+script+ie	605	13	12	954	off+write+ion	description
de+sert+ie	620	46	7	340	off+leave+ion	desertion
dict+ie		(15)	(33)	(1506)	say+ion	diction
fract+uur	578	34	20	797	break+ure	fracture
nov+iteit	738	9	19	356	new+ity	novelty
pend+ant	679	75	8	231	hang+ant	counterpart
pict+o+gram	679	4	3	56	picture+o+write	pictogram
puls+ar		(13)	(12)	(995)	throb+er	pulsar
re+cid+ive		(11)	(12)	(1069)	back+fall	relapse
re+flect+or	629	19	6	480	back+bend+er	reflector
tract+ie		(2)	(37)	(1963)	pull+ion	traction
voc+aal	621	51	29	2250	call+al	vocal
Means	644	31	13	683		

Appendix C (continued)

Word	RT	Fsurf	FBase	Vf	Nf	English Translations	
Germanic, high Constituent Frequency							
						constituents	full form
be+hoeft+ig	595	51	10297	16	7223	be+need+ish	needy
draag+baar	550	47	11963	81	20209	bear+able	bearable
eis+er+es		(8)	(5691)	(19)	(8883)	claim+er+FEMALE	claimant
gekk+erd	643	11	5822	17	6401	foolish+er	fool
groei+sel	645	14	8425	50	11397	grow+ee	growth
handel+baar	558	20	6942	251	26220	trade+able	tradeable
her+kies+baar	653	4	7973	80	11955	re+elect+able	re-electable
klaag+ster	667	9	1544	29	3113	complain+er (FEM)	complainer
leeg+heid	553	36	5451	29	6948	empty+ness	emptiness
leuk+heid	602	3	4026	3	4057	jolly+ness	jollity
on+kund+ig	627	101	103	141	6783	un+knowledge+ish	unknowledgeable
proev+er	575	17	2223	46	4819	taste+er	taster
toon+der	666	43	9400	56	18515	show+er	someone who shows
wend+baar	601	24	2613	17	4551	turn+able	turnable
Means	611	29	5906	63	10169		
Germanic, low Constituent Frequency							
bad+er		34	558	4	637	bathe+er	bather
ge+zwets	648	26	24	2	60	ing+blather	blathering
gluiper+ig		45	0	3	73	shifty-eyed person+ish	like a ...
goei+erd	628	13	1312	3	894	good+er	kind soul
griep+erig	697	9	284	7	342	flue+ish	ill with flue
hut+achtig		(2)	(1635)	(18)	(1955)	hut+like	hutlike
krui+er	621	76	19	2	290	carry+er	carrier
ribbel+ig	699	7	53	2	60	rib+ish	ribbed
scharrel+aar	637	19	379	8	545	rummage+er	rummager
snoep+erij	581	9	353	12	524	eat sweets+ery	the eating of sweets
splijt+baar	674	24	248	8	412	split+able	splitable
stevig+heid	575	53	3299	3	3561	firm+ness	firmness
viez+ig	658	15	1157	6	1312	dirty+ish	dirty-ish
voogd+es	691	26	807	16	1786	guardian+FEM	female guardian
Means	647	25	721	6	890		

Materials for Experiment 3: RT: response latency; Fsurf: Surface Frequency, FBase: Base Lemma Frequency; Vf: Base Family Size; Nf: Base Family Frequency. Means per group after removal of error-prone items, the items listed without a mean RT.