Studia Anglica Posnaniensia 40, 2004

LEXICAL-LEVEL REPRESENTATION OF MORPHOLOGICALLY COMPLEX WORDS: EFFECTS OF PRIMING POLISH COMPOUND WORDS WITH STEM- OR COMPOUND-RELATED ASSOCIATES

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ABSTRACT

This paper presents a priming experiment designed with the aim of throwing light on the representation of Polish compound words in the mental lexicon. It starts with a review of theoretical approaches to the issue of the lexical representation of morphologically complex words. Taft and Forster's (1975) affix stripping model is then contrasted with Butterworth's (1983) Full Listing Hypothesis, and implications stemming from these two proposals for the way compound words are stored in the lexicon are subsequently discussed. The paper then reports on the word fragment completion experiment conducted with a group of forty native speakers of Polish, who were asked to complete fragmented Polish compound words preceded by primes semantically related to either the meaning of the whole compound or to its initial and final stem. Results are compared with the baseline (control) condition and interpreted against the existing theoretical proposals concerning the storage of morphologically complex words in the mental lexicon. It appears that information concerning the internal structure of morphologically complex words is consciously employed by language users in the course of performing a word fragment completion task. Results further indicate that words semantically related to the meaning of compounds act as more efficient primes than words related to either their initial or final stems.

1. Theoretical approaches to the representation of morphology in the mental lexicon

The issue of the representation and processing of morphologically complex words has received much attention in the psycholinguistic literature (see Aitchison 1987; Hankamer 1989; Henderson 1985, 1989; Laudanna and Burani 1985; Segui and Zubizarreta 1985; Taft and Forster 1975). As Hankamer (1989) observes, most discussion on the processing of morphologically complex words has focused on the issue of their representation in the mental lexicon, as well as the issue of whether their processing involves parsing into component parts. The three logical possibilities regarding the lexical representation of morphologically complex words have been formulated by Hankamer (1989). According to the first of them, all forms of morphologically complex words may be listed in the lexicon, without, however, any representation of their internal structure and without connections obtaining between morphologically related entries. The second possibility is that all forms of words may be listed in the lexicon, along with some representation of their internal structure and connections between lexical entries for morphologically related words. Finally, the third option claims that only basic representations of roots and affixes, i.e., building blocks of complex words, should be listed in the lexicon.

The three positions enumerated above are quite rigid and mutually exclusive. While the first of them has never been actually considered in its pure form by any scholars of language processing, the second one has been contemplated in various modified forms, and the third has had a small number of adherents. The most prominent among the followers of the third view have been Taft and Forster (1975), whose so-called *affix-stripping*, or *decomposition* model of lexical access postulates that morphologically complex words sharing a root are stored in the lexicon under that single, root heading and that lexical access is preceded by stripping the complex word of all its affixes, after which lexical lookup of the root can take place. Once the root entry has been located, the process of affix checking takes place. Taft and Forster's model does not, however, elaborate on the exact manner in which affix information is stored within the root-headed entry. Even if the affix-stripping model allows storage economy, it has been severely criticized by a number of psycholinguists (see Aitchison 1987; Butterworth 1983; Henderson 1985, 1989, for an extensive discussion). The most serious criticism of the affix-stripping hypothesis concerns the fact that a mere listing of affixal conjunctions it presupposes fails to express word-formation rules governing the order of application of affixes, phonological and orthographic interactions between roots and affixes, as well as restrictions upon conjunctions. Thus, even though under the decomposition model, the lexicon is relieved of the burden of replicating the root for each derived word in which it participates, it is severely "overloaded" with word-formation rules governing interactions between various root-affix combinations.

The second possible way of representing morphologically complex words has found its most potent manifestation in the so-called Full Listing Hypothesis (FLH), proposed by Butterworth (1983) in reaction against the affix-stripping treatment of morphologically complex words. According to the FLH, each complex word has its own, separate entry in the mental lexicon. Two variants of the FLH have dominated psycholinguistic accounts in recent years. The FLH-A version holds that complex words have their own lexical entries which include a representation of their morphological structure. To provide an example, the word *forgetful* has a lexical entry of its own, but the entry contains a morphological analysis of the word: (*for*-(*get*)-*ful*). The B version, in turn, presupposes that every word has its own entry and that all entries for morphologically complex words are linked to a basic entry for the uninflected or root word. Thus, *forgetful* has its own lexical entry in the mental dictionary, which, along with the entries for *unforgettable*, *forgettable*, *forgetting*, etc., is linked to the basic entry *get*. Under this version of the FLH, the basic entry is called the *nucleus* and the remaining entries clustered around the nucleus are its *satellites*.

More recently, Hankamer (1989) has argued that the FLH cannot stand as a universal model of human word processing in all languages. This is due to the fact that the degree of spontaneous new-word formation during normal speech varies quite radically between languages. To provide an example, whereas English speakers rarely produce new words they have never used before, so that the words they do use may be very likely stored as wholes in the mental lexicon, speakers of agglutinative languages (such as Turkish, for example) have to construct words anew when producing language. The virtually unlimited number of long words that can be produced in such languages makes their storage in the mental lexicon as wholes quite unlikely, so Hankamer suggests the possibility that the correct model for all languages is a mixed one in which some morphologically complex forms are listed, whereas others understood via a parsing mechanism, recognizing first the root and then successive suffixes. She also acknowledges the alternative that morphologically simple languages like English may be full-listing ones, whereas agglutinative languages like Turkish may be lexical-parsing.

A similar claim for Italian speakers has been put forward by Laudanna and Burani (1985), who have suggested a full-listing model with entries for whole words and entries for morphemes. On this account, a complex word is accessed by activating its full entry. Morphological composition of such a complex word is represented by pointers extending from the full entry to the component morpheme entries, the suggestion reminiscent of Butterworth's FLH-A version. Segui and Zubizarreta (1985) have also opted for a full-listing model, in which prefixed words are accessed via entries for prefixed forms, whereas suffixed words are accessed via entries for their roots. Such roots, according to Segui and Zubizarreta, have pointers to the separate entries for suffixed forms, making morphological information about them available for processing.

An interesting treatment of morphologically complex words has been offered by Tyler, Waksler, and Marslen-Wilson (1993). They have proposed two different types of representation for derived words: one for semantically transparent and another for opaque forms. Under this account, the lexical entry for transparent forms, such as, for example, *government*, consists of the stem morpheme [*govern*] and a link to the suffix [*-ment*]. The same stem morpheme also functions as the lexical entry for the morphologically simple form *govern*. Recognition of the word *government* involves access of the stem morpheme and the associated affix. In contrast, semantically opaque derived words are not represented in the lexical entry in terms of their original morphological structure [stem + affix], but as morphologically undecomposed forms. Thus, the lexical entry for words like *department* is not related to words containing phonologically identical but semantically unrelated stems (as in *departure* or *departed*). These have their own separate representations consisting, respectively, of the free stem {*depart*}, linked to the affix {*ure*} and {*ed*}.

Typically, the various approaches to the representation of morphologically complex words have been tested by psycholinguists in priming experiments, which measure the effect of presenting either an identical or otherwise related item on a person's subsequent performance involving the repeated item or an item related to the prime (see, for example, Meyer and Ruddy 1974; Monsell, 1985 for a full discussion of components of priming). A typical priming experiment involves a priming encounter and a probe encounter. For another set of items, there is just one encounter, providing the baseline against which priming effects can be assessed. Experiments employing the priming paradigm usually require subjects to perform some kind of task, such as naming (reading out loud a presented word), lexical decision (deciding if a presented string of letters constitutes a word or not), word fragment completion (completing a word some of whose letters have been removed and replaced with a hyphen), or categorization (deciding if a presented item is concrete vs. abstract, animate vs. inanimate, etc.), and the effects of a previously encountered prime on their performance are assessed against the baseline data. The rationale for employing the priming paradigm for investigating the lexical representation of morphologically complex words is that, depending on how these words are stored in the mental lexicon, various priming effects should obtain for their roots and affixes. To provide an example, if the word's morphological representation consists of a root, to which an appropriate affix is added in the course of language processing, as Taft and Forster's (1975) affix-stripping model would have us believe, then presenting an affix as a prime should not affect the subsequent processing of the word containing this affix, since they are stored separately and thus cannot influence one another in the course of language processing. On the other hand, if the FLH is a true account of the way morphology is represented at the lexical level, then such a priming effect should obtain, as both versions of the full-listing hypothesis assume that complex words have entries preserving the representation of their morphological structure and thus roots are amenable to being primed with the affixes with which they are connected in storage.

2. Lexical morphology and compounds

While most of the priming research concerning the representation of morphology in the mental lexicon has dealt with derivational forms, much less has been written about the representation and processing of compounds. As Henderson (1985) rightly observes, most of the interest in compounds has been taxonomic, as linguists have looked for the phonological, orthographic, syntactic, and semantic criteria for distinguishing compounds from derivational forms and phrasal idioms. Henderson goes on to say that, since the overwhelming majority of compounds are semantically unpredictable, it would be logical to claim that they possess their separate entries in the mental lexicon. She also acknowledges the possibility that compound-specific lexical entries may be linked to some extent with the separate entries for their constituent stems. Among the most prominent characteristics of compounds are, in addition to their semantic unpredictability, the wide variety of compositional rules which govern the formation of compounds and lack of consistency as to which stem in a compound is pivotal semantically.

With regard to the diversity of compositional rules governing compound creation, Henderson (1985) gives an example of the word *man,* which enters into such compounds as *headman*, *headhunter*, *milkman*, *garbageman*, *snowman*, *handyman*, *best man*, or *workman*. In each of these words the relationship between the stem *man* and its neighboring stem is different. Thus, in *headman*, it is about playing some role, in *milkman* – about delivering something, and in *garbageman* – about taking it away. Similarly, while in *handyman* the man is *handy*, in *best man* the man does not really have to be best, and a *snowman* is not a man at all. Turning now to the issue of which stem is more basic and which functions as a modifier, a similar inconsistency can be observed. To provide a few examples quoted by Henderson, whereas in the compound *jailbird* the word *jail* seems pivotal, the reverse is true of *penknife*, which is more *knife* than *pen*.

With respect to compound words, a modification of Taft and Forster's (1975) affix-stripping model was tested in their 1976 priming experiment. Taft and Forster have suggested that in the course of processing morphologically complex words, it is the initial syllable, or rather, what they refer to as the *Basic Orthographic Syllabic Structure* (BOSS), that plays the dominant role in lexical access. Under this view, all the complex words sharing the same BOSS (e.g., *candle*, *candid*, *candelabra*, *candidate*, etc.) have a common lexical entry, headed by the BOSS (*cand*). One consequence this modification of the affix-stripping model has for compound processing is the fact that they are recognized via successful matching of their initial stem. In their experiment, Taft and Forster presented participants with compound nonwords, some of which were composed of two legitimate words, some of which included two nonword stems;

still others contained the leftmost word and the rightmost nonword constituents, or the leftmost nonword and the rightmost word constituents. Reaction times obtained for these nonwords in a lexical decision task revealed that participants took longer to reject nonwords composed of two words and nonwords in which the leftmost constituent was a word than they did nonwords consisting of two nonword constituents or those in which the rightmost constituent was a word. According to Taft and Forster (1976), such a result supports the role of the BOSS they postulate in the processing of complex words and the special status of the initial stem in the course of processing compounds.

Monsell (1985) investigated processing differences between semantically transparent (*beanpole*) and opaque (*cocktail*) compounds, but found equal priming effects for both types primed with their stems (*pole* and *tail*, respectively). In contrast to these results, Osgood and Hoosain (1974), quoted in Henderson (1989) and Wilson (1984), quoted in Henderson (1989), found that only transparent compounds, but not opaque ones, primed their individual constituents. It seems then the results of priming experiments conducted with compounds are rather mixed and inconclusive.

Inspired by research into morphologically complex words and by the need to address the issue of priming with respect to compounds, I carried out an experiment whose purpose was determining whether Polish compound words are stored in a way preserving morphological information concerning their stem components and whether this information becomes available in the course of their processing. The task employed to test the effects of priming was that of word-fragment completion. In the word fragment completion task, participants are presented with degraded stimuli, which are fragments of previously studied or nonstudied items (*t* __ *b* __ *l* __), and are asked to complete fragments with the first solution that comes to mind (*table*). The probability that a particular word will be generated in a word fragment completion increases if an identical word has been presented in the study phase of the experiment. If the study phase of the experiment requires participants to conceptually manipulate the words (for example, categorize them according to whether they denote animate or inanimate things, etc.) then priming is believed to occur not only at the lexical level (level of word forms), but also at the semantic level (level of meaning representations). Under such circumstances, participants' performance on a word fragment completion is enhanced not only by the presentation of an identical word in the prior study phase but also by the presentation of a semantically related word. Most researchers (see Challis and Brodbeck 1992; Gardiner 1988; Hamann and Squire 1996; Neill, Beck, Bottalico and Molloy 1990; Roediger and Challis 1992; Weldon 1991, 1993) agree that the word fragment completion task can be treated as reflecting both data-driven and conceptually-driven memory processes and as a reliable measure of lexical and semantic-level activation accompanying the processing of linguistic stimuli. Because of these characteristics, the word fragment completion task has been employed in the psycholinguistic research to investigate the organization of the mental lexicon in bilingual (Smith 1991) and trilingual (Schonpflug 2000) speakers and to probe the activation of literal and figurative senses of idioms during the comprehension of figurative language (Giora and Fein 1999).

In the study described in this paper, the word-fragment completion task has been employed to test the presence of priming effects with the use of primes related to the meaning of the initial stem, the second, "pivotal" stem, or the entire compound word and hence to verify the various proposals put forward with regard to the representation of morphologically complex words in the mental lexicon. A detailed description of the study and its rationale is provided in the remainder of this paper.

3. The study

As has been mentioned earlier, word-fragment completion can be taken to reflect both lexical- and semantic-level processes in language processing. Following this assumption, if morphologically complex words are stored in a way preserving their internal structure, then presenting a word semantically related to one of its constituents should facilitate participants' completion of the fragmented compound presented later. To illustrate with an example, if the entry for the compound word *muchołapka* 'flytrap' preserves information about its constituents (*mucha* + *łapka*, 'fly + trap/little paw'), then presenting the semantic associate of *łapka* 'little paw', such as *piesek* 'doggie' should lead to a more successful completion of the fragmented compound M __ C __ O __ A __ K __ than presenting an unrelated word (e.g., *drzewo* 'tree') in the study phase. The question of which semantic associates (related to the first stem, the second stem, or to the entire compound) would be more effective as primes crucially depends on the specific models proposed for morphologically complex words and reviewed in section 1 of this paper. Specific predictions of these models with regard to the priming effects of the three types of prime are discussed next.

Beginning with Taft and Forster's proposal, compound words are accessed via the recognition of their initial stem, which implies that primes related to the initial stem should be more effective than those related to the second stem or to the entire compound. Thus, priming *jasnowidz* 'clairvoyant', consisting in the Polish compound of two stems: *fair* + *viewer*, with *ciemny* 'dark', a semantic associate to the word *jasny* 'fair', should be more effective than priming it with *kino* 'movies', a semantic associate to the word *widz* 'viewer', or *wróżka* 'fortune-teller', a semantic associate to the whole compound.

In turn, if the B version of the FLH is an adequate account of the representation of morphologically complex words, then compounds are likely to be stored holistically and they should be all connected to the *nucleus*, or their pivotal form, which, in a way, acts as the frequency counter for the entire set of words (its *satellites)*. As Henderson (1989) has rightly observed, the nuclear model implies a special status enjoyed by the nucleus in the course of processing complex words. In terms of compound processing, the fact that compound words are satellites connected to their nuclear stem would imply that presenting a word semantically related to the nuclear stem in the study phase of the word fragment completion experiment should facilitate subjects' performance on the subsequent task involving completing fragmented compounds to a larger extent than priming the compound either with the word semantically related to the first stem or to its meaning as a whole. Thus, unlike the scenario proposed above for the Taft and Forster's model, priming *jasnowidz* 'clairvoyant', with *kino* 'movies', (semantic associate to the pivotal stem) should be more effective than either priming it with *ciemny* 'dark' (associate to the initial stem) or with *wróżka* 'fortune-teller' (associate to the whole word).

On the other hand, if the A version of the FLH is true, then the nucleus of a complex word does not enjoy a prominent status in terms of storage and processing, even if the morphological structure of the complex word is represented at the lexical level. Thus, even if information about the morphological makeup of the word *jasnowidz* (*jasny* + *widz*) 'fair + viewer' is present in the lexical entry for this word, the stem *widz* 'viewer' does not otherwise behave as a more basic or nuclear entry than the stem *jasny* 'fair'. This indicates that presenting a word either semantically related to *widz* (i.e., *kino* 'movies' in our example*)* or to *jasny* (i.e., *ciemny* 'dark' in our example) in the study phase should affect participants' performance on the word fragment completion task in comparable ways and that substantially more priming should be obtained for the word *wróżka* 'fortune-teller', semantically related to the meaning of the whole compound.

3.1. Participants

Participants were forty native speakers of Polish, studying English as a second language at Adam Mickiewicz University, Poznań, Poland. They agreed to participate in the experiment during their classes and were tested in several groups at the times regular classes were scheduled for each group. One group consisted of six female students, aged 20-22; another of 12 students (one male and 11 female) aged 23-24, yet another of six female and five male students aged 20-21; and the fourth group was made up of seven female and four male students, whose average age was 21.3 years.

3.2. Materials

Materials consisted of 30 Polish compound words which have been drawn from *The New Kościuszko Foundation Dictionary* (2003), as well as of 90 words serving as primes. The compounds were either adjectives (e.g. *krwionośny*, 'circulatory') or nouns (e.g. *korkociąg* 'screwdriver'), and the initial assumption was to ensure that they were consistent in terms of which stem acted as a nucleus and which as a modifier. Despite the attempts to ensure this consistency, upon a closer scrutiny of the experimental materials, I noticed that few compounds did not conform to this rule as it was either difficult to determine which of the two stems was more basic or both of them could be viewed as having an equal contribution to the semantics of the complex word (for example *korkociąg* 'screwdriver', where *korek* 'cork' seems more central to the meaning of the compound than *ciąg* 'pull'*)*. As such inconsistencies could undermine the validity of the research hypotheses formulated above for testing the B version of the FLH, for which determining that the second stem is more pivotal semantically than the first one is of crucial importance, I decided to modify the original research questions and focus exclusively on the comparison of priming effects obtained with primes related to either initial or final stems on the one hand and to primes associated with the meaning of the whole compound on the other. Such a modification of the research questions could allow differentiating between the Full-Listing Hypothesis and Taft and Forster's affix-stripping model, but could not distinguish between the two versions of the FLH. Thus, demonstrating that primes related to the initial stem facilitate performance more substantially than primes related to the meaning of the whole compound would indicate support for the affix-stripping model, whereas obtaining more priming for compound-related primes than for initial stem-related primes would be taken as support for the Full Listing Hypothesis. Additionally, testing the effect of priming with words related to the second stem, which in most compounds appeared to be semantically pivotal, could help throw light on the availability of the internal semantics of compound constituents in the course of their processing by language users.

As mentioned earlier, a list of 30 Polish compound words was prepared for the experiment. In order to obtain the relevant primes for initial stems, second stems, and the whole words, three separate lists were subsequently prepared. One list consisted of initial stems (e.g. *korek* 'cork', being the first stem of the compound *korkociąg* 'screwidriver'; *dwa* 'two', making up the compound *dwulicowy* 'two-faced'; or *jasny* 'fair', entering into the compound *jasnowidz* 'clairvoyant'. The second list consisted of final stems (e.g. *ciąg* 'pull', being the second stem of *korkociąg*; *lico* 'face', making up the compound *dwulicowy*; or *widz* 'viewer', making up the compound *jasnowidz*). Finally, the third list consisted of the compounds themselves. Each list was then presented to 15 native speakers of Polish with the request to look at each word in turn and provide the first word that comes to mind. Responses elicited from the informants were then scrutinized and the most frequently occurring associate was selected for the word fragment completion task. To provide an example, for the stimulus words making up the compound *korkociąg* 'screwdriver'), the most frequent responses were as follows: *korek* 'cork' – *zatyczka* 'plug', *ciąg* 'pull' – *wóz* 'cart', *korkociąg* 'screwdriver' – *szampan* 'champagne'. A complete list of the thirty compound words, along with three types of primes with which they were paired in the experiment, is provided in Appendix 1. In addition to stem-related or compound-related primes, a list of 30 control words was prepared, one for each compound, serving as the baseline against which any priming effects could be compared. The control words were unrelated in any way to either the first or the second stem or to the whole compound.

Following the construction of the relevant primes, four experimental lists were prepared. Each list consisted of 60 rows in which prime words were printed alternatively with compound words. The compound words were fragmented, i.e., some of their letters had been removed and replaced with a hyphen. The first list contained control (unrelated) words, along with the compounds with which they were paired, the second list contained initial stem primes with their corresponding compounds, the third one – nuclear stem primes with the corresponding compounds, and the fourth one – compound-related primes. Each list type was delivered to ten participants. A fragment of an experimental list is provided in Appendix 2.

3.3. Design

The design was a one-way analysis of variance (ANOVA), with prime type (initial stem-related, nuclear stem-related, compound-related, control) as an independent variable and the number of appropriately completed fragmented compounds as a dependent variable. In addition, means obtained for each prime type were compared in paired samples t-tests to see the effects of priming with each type of prime.

3.4. Procedure

The data were collected at the time regular classes were scheduled for each group. At the beginning of the session, participants were instructed that they were about to take part in the experiment testing their ability to complete Polish fragmented words. The experimental sheets were next distributed to each person, with the instruction to cover the sheet and expose only one line at a time. At the signal provided by the experimenter, participants were to uncover the first line, look at the word (the prime), read it carefully and decide if the word denoted a concrete or abstract thing. The purpose of this task was to ensure that

participants would process the prime carefully and that the meaning of the prime would become fully activated. Participants were allowed 10 seconds for each word, after which the experimenter gave the signal to proceed to the next line on which a fragmented compound was printed. They were instructed to try to complete the degraded word with the first word that came to mind. The time limit for completing the degraded stimulus was 30 seconds. After the 30 seconds were over, the experimenter gave the signal to proceed to the next line, where another priming word was printed. Participants were not allowed to look back at the words they had completed but to focus only on the word they were currently reading. In this way, the lists were read and completed in about 20 minutes.

3.5. Results

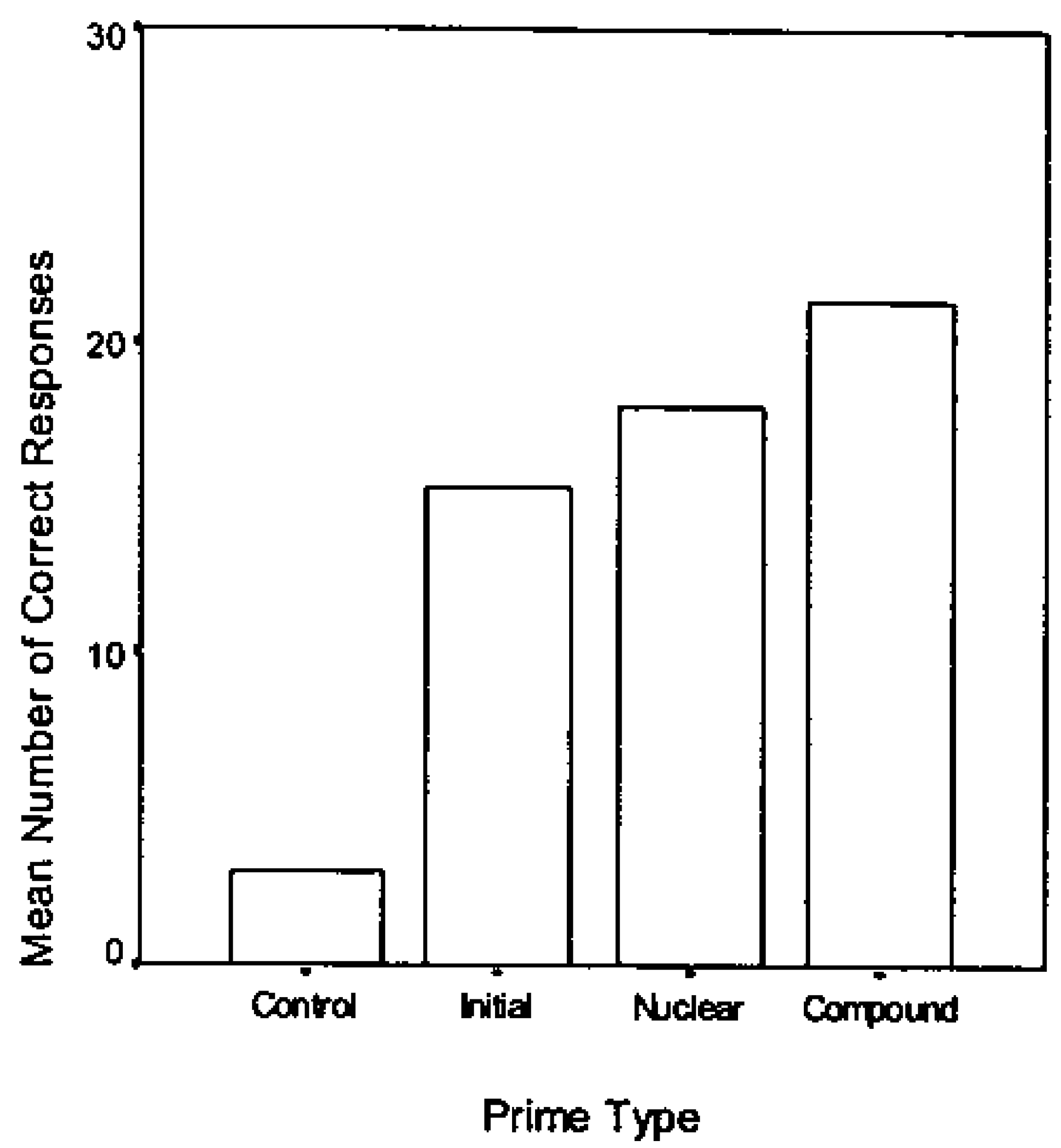
The completed sheets were collected from the participants and analyzed separately according to the type of priming word they included. Correct responses from each subject were next calculated and entered into the statistical program (SPSS 11.5 for Windows). As mentioned earlier, a one-way ANOVA was next conducted to verify the effect of prime type on the number of correct responses in the word fragment completion test. The means and standard deviations for the correct responses on the test and the four prime types are summarized in Table 1.

Table 1. Means and standard deviations for the four prime types and correct responses

	Prime Type							
	Initial		Nuclear		Compound		Control	
Variable	M	SD	M	SD	M	SD	M	SD
Correct Responses	15.3	6.55	17.9	5.89	21.3	5.5	3.0	2.26

As can be seen in Table 1, prime words related to the meaning of the overall compound (referred to as Compound Primes) elicited the biggest number of correct responses, with the mean score of M=21.3. Initial and Nuclear Primes elicited a comparable number of correct responses, with the mean scores of M=15.3 and M=17.9, respectively. All types of primes obtained a considerably bigger number of correct responses than Control Primes, whose mean score was M=3.0. These differences are graphically illustrated in the bar chart presented in Figure 1.

Figure 1. Mean number of correct responses obtained for fragmented words primed with control words, initial-related associates, nuclear-related associates, and compound-related associates



The graph shows big differences between control primes on the one hand and the three remaining types of prime, as well as differences between the effects of initial, nuclear, and compound primes. It appears that compound primes were most effective in terms of facilitating correct responses on the word fragment completion test. Next in terms of facilitation come nuclear primes, which obtained a slightly higher mean than initial primes. We can thus conclude that substantial priming effects were demonstrated for fragmented words accompanied by initial, nuclear, or compound-related primes in comparison to the baseline (control) condition. To see if the effect of prime type on the correct responses was significant, a one-way ANOVA was conducted, whose results are summarized in Table 2.

Table 2. One-way analysis of variance (ANOVA) for effects of prime type on correct responses

Variable and source	df	SS	MS	F	Sig.
Correct Responses					
Between Groups	3	1906.28	635.43	22.58	0.00
Within Groups	36	1013.10	28.14		

As shown in the table, the ANOVA revealed a significant effect of prime type on correct responses ($F(3, 36) = 22.58$, $p < 0.0001$), which provides support for the major prediction advanced here, namely, that different prime types will differentially affect the processing of morphologically complex words by language users.

To statistically verify which prime type was most effective in facilitating participants' responses to the fragmented stimuli, paired samples t-tests were next conducted in the item analysis. Summary of the paired samples statistics for the contrasted pairs (compound versus initial, initial versus nuclear, compound versus nuclear, compound versus control, initial versus control, and nuclear versus control) is provided in Table 3.

Table 3. T-comparisons for the three prime types

	M	SD	SE	t	df	Sig. (2-tailed)
Pair 1 Compound – Initial	1.70	2.77	.51	3.36	29	0.002
Pair 2 Initial – Nuclear	–.43	2.14	.39	–1.11	29	0.277
Pair 3 Compound – Nuclear	1.27	3.16	.58	2.19	29	0.036
Pair 4 Compound – Control	6.10	2.11	.38	15.86	29	0.000
Pair 5 Initial – Control	4.40	1.99	.36	12.31	29	0.000
Pair 6 Nuclear – Control	4.83	2.53	.46	10.45	29	0.000

As seen in the table, the mean score for correct responses obtained in the compound, initial, and nuclear prime conditions (Pairs 4, 5, and 6) was significantly greater at the $p < .0000$ level than the mean score in the control condition. This result confirms our earlier ANOVA for the effects of prime type on the number of correct responses. In addition, t-comparisons yielded a significant contrast between priming effects obtained for compound- and initial-related primes ($t(29) = 3.36$, $p < 0.01$) and between the effects obtained for compound- and nuclear-related primes ($t(29) = 2.19$, $p < 0.05$). Prime words related to the meaning of the whole compounds thus resulted in a significantly greater amount of facilitation than either primes related to their initial or final stems.

4. Discussion

Overall, analysis of the data obtained in the experiment revealed a significant effect of primes on participants' subsequent completion of fragmented compound stimuli. Priming words associated with initial stems, nuclear stems, and overall compounds turned out to be statistically significantly more efficient than control (unrelated) primes. Of the three types of primes which turned out to facilitate performance on the word fragment completion task, primes related to the overall meaning of fragmented compounds were most efficient, eliciting the highest number of correct responses. Primes associated with initial and nuclear stems of compound words were relatively comparable in terms of facilitating participants' performance, and both initial- and nuclear-related primes were considerably less effective than compound-related primes. This difference turned out to be statistically significant.

These results allow rejecting the affix stripping approach to the way in which morphologically complex words are stored and processed by language users. As will be recalled from section 3, if Taft and Forster's (1975) account of morphologically complex words were accurate, then significantly more priming should be obtained for fragmented stimuli following primes related to their initial stems than for those following primes related to either the second (nuclear) stems or to the entire compound words. This hypothesis is consistent with the primacy of initial stems in processing compounds postulated under the affix-stripping model. Yet, contrary to this assumption, words related to initial stems failed to demonstrate priming superiority and actually did much worse than either primes related to the meanings of the entire compounds or primes related to their second (nuclear) stems. The difference between priming effects obtained for initial primes was statistically significantly lower than that obtained for compound-related primes. With regard to the difference between initial and nuclear primes, whereas the priming difference between them was relatively low and statistically insignificant, the obtained data did reflect a smaller number of correct responses following initial (M=15.3) than nuclear (M=17.9) primes.

The data then seem to support the view that morphologically complex words are stored in accordance with the Full Listing Hypothesis put forward by Butterworth (1983). As mentioned earlier, distinguishing between the two versions of the FLH may be problematic, due to the characteristics of the stimulus materials. Whereas the FLH B presupposes superiority of nuclear (semantically pivotal) stems in the course of processing compound words, the A version does not postulate any such superiority of nuclear over initial stems and merely assumes that the morphological structure of a complex word is represented at the lexical level. Given these differences, if the B version were true, then priming fragmented compounds with words related to their nuclear stems should be more effective than priming them with words related to either initial stems or entire compounds. At first sight the data seem compatible with the A version of the FLH, as nuclear-related primes did not turn out to be superior to compound-related primes. They did, however, appear more efficient in facilitating participants' performance than initial-related primes. On the other hand, as mentioned earlier, identifying nuclear primes in some compounds was difficult, so this interpretation should be treated with caution. Probably the only reliable conclusion we can draw from the obtained data is that information concerning the

internal structure of morphologically complex words becomes available in the course of their processing by language users, the view consistent with both versions of the FLH.

The availability of information concerning the internal structure of morphologically complex words was clearly visible in incomplete answers provided by participants to degraded stimuli. In many cases, participants completed just one stem of the degraded compound word, which was on all occasions the stem related to the preceding prime. To provide an example, many participants faced with the fragmented compound c _ a _ n _ k _ i _ _ ni _ (*czarnoksiężnik* 'sorcerer', made up of two Polish words *czarny* 'black' and *książka* 'book'), provided only the beginning of the compound c **z** a **r** n **y** k _ i _ _ ni _,[1] doing so only in cases when the preceding prime was a semantic associate to the initial stem, i.e., the word *biały* 'white'. Similarly, where the compound *jednogłośny* 'unanimous', made up of two Polish words, *jeden* 'one' and *głos* 'voice', was primed with the associate to the initial stem *dwa* 'two', many participants filled out only the beginning of the fragmented stimulus j **e** d **n** o _ _ o _ n _ , failing to complete the whole compound. Some other examples include c **u** d **z** o _ _ s w _ (*cudzołóstwo*, 'adultery'), primed with *własny* 'own', which is the associate of the initial stem *cudzy* 'somebody else's', or k **r** **ó** t **k** o _ i _ _ (*krótkowidz*, 'short-sighted'), primed with the word *długi* 'long', which is semantically related to the first stem *krótki* 'short'.

A similar priming effect was observed for final compounds. Thus, the prime *pięść* 'fist'/, related to the nuclear stem *bójka* 'fight', making up the compound *bakteriobójczy* (*bactericidal*, made up of the words *bacteria* + *fight*), induced some participants to fill only the second part of the degraded compound, as in b _ _ t _ r _ _ b **ó** j **c** z **y**. Likewise, completion of the second part of the compound *gradobicie* ('hailstorm', made up of two words 'hail + hit'), as in _ r _ d **o** b **i** c **i** e, must have resulted from the facilitating effect of the preceding prime *uderzać* 'strike'. Other examples of completing the second stem only as a result of the stem-related prime include elektrowóz ('electric locomotive', made up of 'electric + cat'), filled by some participants as _ **l** _ k _ r _ w **ó** z, most probably because of the preceding prime *koń* 'horse', or *zleceniodawca* (made up of 'order + donor'), completed partially as _ l _ _ en _ o **d** **a** w **c** a, as a result of the preceding prime *krew* 'blood'. The extent to which participants performing the word fragment completion task analyzed the compounds into their stems and were influenced by the preceding priming words in their answers is further illustrated by ingenuous answers provided to the degraded version of the stimulus *rakotwórczy* 'carcinogenic', primed with *artysta* 'artist', which is an associate to

[1] The letters filled out by participants are marked in bold.

the second stem *twórca* 'creator'. Four out of ten participants faced with the degraded stimulus _ a _ o _w _ _ c _ y came up with the answer _ a _ o _w **n i c z** y, which suggests the inappropriate completion *malowniczy* 'picturesque', undoubtedly evoked by the associate *artysta* 'artist'. Such examples clearly indicate that participants consciously resorted to analyzing the internal structure of the degraded compound words, which provides additional support for the view that, despite being stored as whole words, compounds preserve in their lexical entries detailed information concerning their internal structure.

The data reported here are likewise compatible with the results obtained by Monsell (1985) and discussed earlier in the paper. Monsell found equal priming effects for transparent and opaque compounds primed with both initial and final stems. While the compounds employed in the study described here were overwhelmingly transparent and so testing whether identical effects would hold for opaque ones was impossible, the fact that both initial and final stems appeared comparable in terms of priming efficiency is consistent with what Monsell reported in his study. Verifying whether any differences would obtain for compounds varying in terms of their transparency, as well as differentiating between the two versions of the FLH remain to be investigated in the future.

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APPENDIX 1

A list of Polish compound words employed in the task, along with the primes related to the initial stem, the nucleus stem, and the entire word

	Compound words	Initial stem primes	Nuclear stem primes	Compound-related primes
1.	człekokształtne (anthropoids)	facet (chap)	koło (circle)	małpy (monkeys)
2.	mrówkojad (anteater)	owad (insect)	obiad (dinner)	zwierzę (animal)
3.	brudnopis (rough draft)	czysty (clean)	długopis (pen)	zeszyt (note-book)
4.	zleceniodawca (client)	umowa (agreement)	krew (blood)	szef (boss)
5.	muchołapka (flytrap)	owad (insect)	pies (dog)	zabijać (kill)
6.	cudzołóstwo (adultery)	własny (own)	sen (dream)	grzech (sin)
7.	księgozbiór (book collection)	wieczysta (perpetual)	matematyka (maths)	biblioteka (library)
8.	krwionośny (circulatory)	śmierć (death)	ubranie (clothes)	układ (system)
9.	samochód (car)	osoba (person)	nogi (legs)	pojazd (vehicle)
10.	krwiobieg (blood circulation)	śmierć (death)	bieżnia (treadmill)	organizm (organism)
11.	cudzoziemiec (foreigner)	własność (property)	gleba (soil)	obcy (foreigner)
12.	cudzysłów (quotation mark)	obcy (foreign)	wyraz (word)	cytat (quote)
13.	bakteriobójczy (bactericidal)	wirus (virus)	pięść (fist)	środek (remedy)
14.	krótkowidz (short-sighted)	długi (long)	kino (cinema)	oczy (eyes)
15.	krwiożerczy((ferocious)	serce (heart)	świnia (pig)	drapieżny (predatory)
16.	krajoznawstwo (sightseeing)	naród (nation)	wiedzieć (know)	wycieczka (trip)
17.	kosztorys (cost estimate)	cena (price)	kredki (crayons)	oszacowanie (assessment)
18.	korkociąg (corkscrew)	zatyczka (plug)	wóz (cart)	szampan (champagne)
19.	jednorożec (unicorn)	dwa (two)	Wojski (proper name)	róg (horn)
20.	jednogłośny (unanimous)	dwa (two)	tenor (tenor)	zgodny (unanimous)
21.	innowierca (infidel)	obcy (stranger)	Bóg (God)	kościół (church)
22.	rakotwórczy (carcinogenic)	choroba (illness)	artysta (artist)	śmiertelny (lethal)
23.	dwulicowy (two-faced)	trzy (three)	twarz (face)	fałszywy (hypocritical)
24.	czarnoksiężnik (sorcerer)	biały (white)	czytanie (reading)	magik (conjurer)
25.	jasnowidz (clairvoyant)	ciemny (dark)	kino (cinema)	wróżka (fortune-teller)
26.	gradobicie (hailstorm)	deszcz (rain)	uderzać (strike)	opady (precipitation)
27.	górnolotny (high-flown)	dół (bottom)	samolot (airplane)	mądry (wise)
28.	elektrowóz (electric locomotive)	prąd (current)	koń (horse)	pojazd (vehicle)
29.	dwuznaczny (ambiguous)	trzy (three)	Zodiak (Zodiac)	niejasny (unclear)
30.	całodzienny (daylong)	pół (half)	noc (night)	nieustanny (continuous)

APPENDIX 2

Fragment of an experimental list (with initial stem-related primes). English translation is provided in parentheses

facet (chap)
c __ __ e __ o __ s __ __ a _ t _ y /anthropoids/
owad (insect)
m __ __ w __ o __ a __ /anteater/
czysty (clean)
__ r __ d __ o __ i ___ /rough draft/
umowa (agreement)
__ l __ __ e n __ o __ __ w __ a /client/
owad (insect)
m __ c __ o __ a __ k ___ /flytrap/
własny (own)
c __ d __ o __ __ s __ w __ /adultery/
wieczysta (perpetual)
k ___ i ___ g __ __ b __ __ r /book collection/
śmierć (death)
__ r __ i ___ n o __ n __ /circulatory/
osoba (person)
__ a __ o __ h __ __ /car/
obcy (foreigner)
c __ __ z y __ ł __ __ /quotation mark/
wirus (virus)
b __ __ t __ r __ __ b __ j __ z __ /bactericidal/
długi (long)
k __ __ t __ o __ i __ __ /short-sighted/
serce (heart)
k __ __ i __ __ er__ z __ /ferocious/