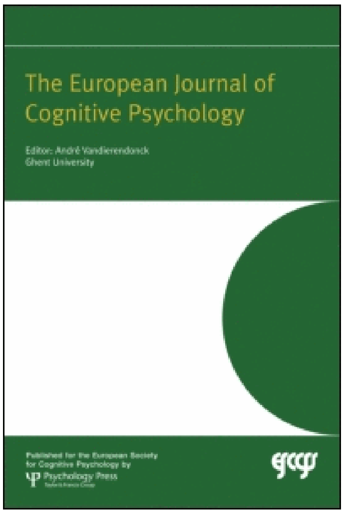

European Journal of Cognitive Psychology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713734596

Is Milkman a superhero like Batman? Constituent morphological priming in compound words

Jon Andoni Duñabeitia [a]; Itziar Laka [b]; Manuel Perea [c]; Manuel Carreiras [a]
[a] Instituto de Tecnologías Biomédicas, and Universidad de La Laguna, Tenerife, Spain [b] Euskal Herriko Unibertsitatea (UPV/EHU), Leioa Biscay, Spain [c] Universitat de València, València, Spain

First Published on: 16 June 2008

To cite this Article Andoni Duñabeitia, Jon, Laka, Itziar, Perea, Manuel and Carreiras, Manuel(2008)'Is Milkman a superhero like Batman? Constituent morphological priming in compound words',European Journal of Cognitive Psychology,

To link to this Article: DOI: 10.1080/09541440802079835

URL: http://dx.doi.org/10.1080/09541440802079835

EUROPEAN JOURNAL OF COGNITIVE PSYCHOLOGY
0000, 00 (00), 1–26

Psychology Press
Taylor & Francis Group

Is *Milkman* a superhero like *Batman*? Constituent morphological priming in compound words

Jon Andoni Duñabeitia
Instituto de Tecnologías Biomédicas, and Universidad de La Laguna, Tenerife, Spain

Itziar Laka
Euskal Herriko Unibertsitatea (UPV/EHU), Leioa Biscay, Spain

Manuel Perea
Universitat de València, València, Spain

Manuel Carreiras
Instituto de Tecnologías Biomédicas, and Universidad de La Laguna, Tenerife, Spain

In the present study, we examined morphological decomposition of Basque compound words in a series of masked priming lexical decision experiments. In Experiment 1, Basque compound words could be briefly preceded by other compounds that shared either the first or second constituent, or by unrelated noncompound words. Results showed a significant priming effect for words that shared a constituent, independently of its position. In Experiment 2, compound words were preceded by other compound words that shared one of their constituents, but in a different lexeme position (e.g., the first constituent of the compound that acted as a prime was the second constituent of the compound that acted as a target). Results again showed a constituent priming effect (i.e., location in the string is not necessary for priming to occur). In Experiment 3, we demonstrated that these priming effects were not due to mere form overlap: pairs of noncompound words that shared either the beginning or the ending chunk did not produce a priming effect. Taken together, the present results converge with previous data on orthographic/morphological priming and provide evidence favouring early morphological decomposition.

Correspondence should be addressed to Jon Andoni Duñabeitia, Departamento de Psicología Cognitiva, Universidad de La Laguna, 38205 Tenerife, Spain. E-mail: jaduna@ull.es

The research reported in this paper has been partially supported by Grants SEJ2004-07680-C02-02/PSIC, SEJ2006-09238/PSIC, SEJ2005-05205/EDU, CSD2007-00012, SEJ2007-60751/PSIC, GIU06/52, and BFI05.310. The authors thank Oxel Uribe for his technical support and Marc Brysbaert and two anonymous reviewers for their helpful comments on an earlier draft. The authors also thank Margaret Gillon Dowens for her immeasurable patience.

http://www.psypress.com/ecp DOI: 10.1080/09541440802079835

Keywords: *Compound words, Morphological priming, Morphological decomposition.*

Spider-Man, *Superman*, *Batman*, *Iron Man*, *Aquaman*. It is easy to see that there is a relationship between all of these words: They all refer to men. But do we need to see Peter Parker to realise that *Spider-Man* is actually a man? Or can we infer this from the superhero's name? And more importantly, when we read *Postman* and *Milkman*, do we also think they have superpowers? Morphological decomposition has been a focus of debate in recent decades for researchers in visual word recognition. However, there is no current consensus about exactly how and when polymorphemic words are decomposed into their constituent morphemes (Diependaele, Sandra, & Grainger, 2005). The main goal of the present paper is to shed some light on this issue via a masked priming procedure with compound words.

Priming paradigms have been largely employed to determine to what extent different types of overlap between words produce facilitation effects. There have been two main approaches to this issue: orthographic priming and morphological priming. A number of orthographic priming experiments have been conducted to test whether form overlap alone is enough to produce facilitation effects. For instance, a recent study by Grainger, Granier, Farioli, van Assche, and van Heuven (2006) revealed that masked orthographic priming can be obtained with primes that contain the initial or ending letters of a target string (e.g., *diffe-DIFFERENT* and *erent-DIFFERENT*). Grainger and colleagues showed that both priming conditions produced significant facilitation relative to an unrelated nonword condition. The magnitude of the priming effects were similar for seven- and nine-letter words preceded either by their initial or ending letter (nonword) chunks, even when the overlap between primes and targets was less than 50%. In contrast, when the primes are words (e.g., as in *shallow-FOLLOW*), there seems to be little consensus in the literature. On the one hand, Chateau, Knudsen, and Jared (2002) found no reliable orthographic priming effects with words sharing the initial letters (e.g., *element-ELEVATOR*; see also Duñabeitia, Perea, & Carreiras, in press, for a masked priming experiment, Marslen-Wilson, Ford, Older, & Zhou, 1996, for a cross-modal priming experiment in English, or Reid & Marslen-Wilson, 2000, for a replication in Polish). On the other hand, Giraudo and Grainger (2003), Exp. 4) found a significant priming effect when using pairs of French words that either shared the final suffix or a nonmorphological ending (e.g., *rouage-PLIAGE* and *stage-PLIAGE*, where *-age* in *stage* does not correspond to a morpheme). More specifically, they found a significant priming effect with a 57 ms SOA (26 and 22 ms, respectively) as compared to a control unrelated condition (see Forster & Azuma, 2000, for similar results). Hence, at present, it is not clear whether masked orthographic priming effects can be consistently obtained between strings that share some of the initial or ending letters (that do not constitute a morpheme), and under what circumstances this can be achieved.

Purely grapheme-based relationships between prime and target have been said to be insufficient to produce facilitation (e.g., *brothel* does not activate *BROTH*; see Rastle, Davis, & New, 2004). In contrast, pairs that share a root morpheme do activate each other in masked priming experiments (e.g., *walker* activates *WALK*; Devlin, Jamison, Matthews, & Gonnerman, 2004; Feldman, 2000; Feldman & Prostko, 2002; Feldman & Soltano, 1999; Longtin, Segui, & Hallé, 2003; Marslen-Wilson, Tyler, Waksler, & Older, 1994; Rastle & Davis, 2003; Rastle et al., 2004; Rastle, Davis, Tyler & Marslen-Wilson, 2000). These results have been taken as evidence in favour of dissociation between morphological and orthographic priming. Furthermore, masked morphological priming effects have been found when both prime and target words share either: (a) the initial root morpheme (e.g., *balayeur*-*BALAYAGE*, in French, where *balayeur* is *sweeper* and *balayage* is the action of *sweeping*, both sharing the root *balai*, meaning *broom*; Giraudo & Grainger, 2001; see also Domínguez, Segui, & Cuetos, 2002); (b) the final morpheme, regardless of whether it is a freestanding or a bound morpheme (e.g., *deform*-*CONFORM* and *revive*-*SURVIVE*, where *form* is a freestanding morpheme and *vive* is a bound morpheme (i.e., cannot stand alone as a word); see Forster & Azuma, 2000; Pastizzo & Feldman, 2004). The main purpose of this study is to resolve the apparent discrepancies between the different outcomes of the experiments on masked orthographic and morphological priming, by investigating morphological and orthographic effects in compounds using the masked priming technique.

One important issue here is that grammars vary widely in the number and type of compounds they use or can generate. In some languages, word compounding is a very productive way to construct novel words (e.g., Basque, Finnish, German, or Turkish; Hyönä & Pollatsek, 1998). For instance, an English driver on a motorway might encounter a *speed indicating panel*, while a German driver will find a *Geschwindigkeitsanzeigetafel*.[1] Thus, languages that are productive in terms of compounding are most appropriate for studying how readers access the meaning of polymorphemic words: Do readers decompose the words down to their morphological constituents before they access the entire word (a prelexical decomposition pathway; see Rastle et al., 2004)? Or alternatively, does decomposition occur after the whole compound word has been identified

[1] The German compound word *Geschwindigkeitsanzeigetafel* is formed by three constituents: *geschwindigkeits* (speed) + *anzeige* (indicate) + *tafel* (board).

(a supralexical decomposition pathway; see Giraudo & Grainger, 2001, 2003)? In this paper, we will present evidence from compound word processing in Basque, a non-Indo-European isolating language with typological traits that are uncommon among European languages (e.g., SOV type, ergative, agglutinative). Basque provides an excellent opportunity for testing compound words, given that its lexicon contains a large number of compounds, and compounding is a frequently employed morphological mechanism (see Duñabeitia, Perea, & Carreiras, 2007b, for an extensive explanation of compounding in Basque).

Recent evidence from eyetracking, naming, and lexical decision experiments has shown that when a reader encounters a compound word, its morphological constituents are rapidly identified and processed (e.g., Andrews, Miller, & Rayner, 2004; Juhasz, Starr, Inhoff, & Placke, 2003; Duñabeitia et al., 2007b). Shoolman and Andrews (2003) stated that "the isolation of subword constituents is a product of an activation process that allows morphemic constituents of multimorphemic strings to activate lexical representations (*black* and *bird* can both activate *blackbird*)" (p. 248). Priming paradigms provide insight about the extent to which the constituents are activated when accessing the whole-word representation of the compound (see Isel, Gunter, & Friederici, 2003, for a review). The seminal work by Monsell (1985) revealed that equal repetition priming effects could be found for the first and for the second constituents. However, the procedure followed in the stimuli presentation in that study could be susceptible to strategic, episodic effects (Jacoby, 1983). Zwitserlood (1994) tried to overcome these episodic effects by using an immediate partial repetition priming paradigm, in which the whole compound word was presented during 300 ms and followed by one of its constituents (e.g., *milkman-MILK*). Overall, she found similar priming effects for first and second constituents. She also replicated these results with a semantic priming paradigm (Experiment 2). These results partially converge with those in Sandra's (1990) study, which revealed that the recognition of transparent compounds (e.g., *MILKMAN*) could also be facilitated by the previous presentation of a word semantically related to one of the constituents (e.g., *woman*). It should be noted that Monsell's, Sandra's, and Zwitserlood's results converge with the results obtained in purely orthographic priming experiments (see Grainger et al., 2006), and as in these studies the authors did not include an orthographic control condition, the outcomes could be understood as morphological priming effects, as well as orthographic priming effects. Jarema, Busson, Nikolova, Tsapkini, and Libben (1999), in a priming paradigm with a 150 ms SOA, showed a different pattern of results. With French compound words (e.g., *haricot vert*, meaning *green bean*) they showed that the preview of the first constituent (*haricot*) benefited the recognition of the compound much more than the preview of the second constituent (*vert*). A replication of this experiment in Bulgarian yielded slightly different results—both constituents exerted a similar influence. Libben, Gibson, Yoon, and Sandra (2003) replicated these last findings in an English experiment (Exp. 2), and also found that the first (e.g., *car*) and second constituents (e.g., *wash*) yielded a similar priming effect on recognition of a compound target (e.g., *car-wash*) when compared to an unrelated condition (e.g., *pen*; see also Duñabeitia, Marín, Avilés, Perea & Carreiras, 2008). Taken together, the evidence from constituent priming indicates that both constituents exert some facilitative influence in the recognition of the compound (Sandra, 1990; Libben et al., 2003; see also Andrews, 1986), though it is still unresolved whether both word-initial and word-final morphemes prime equally or not.

All the previously mentioned priming studies employed prime exposures of at least 150 ms, and thus strategic processes could have affected the results obtained—note that under those conditions both prime and target words were consciously seen and processed. The masked priming paradigm is particularly appropriate to avoid these strategic effects (Forster & Davis, 1984). To the best of our knowledge, there is only one published study providing evidence from a masked constituent priming experiment (Shoolman & Andrews, 2003). In that study, participants were presented with (a) transparent compound words (e.g., *bookshop*), (b) partially opaque compounds (e.g., *jaywalk*, formed by *jay* + *walk*, where whole-word meaning is not derived strictly compositionally from morpheme meaning), and (c) pseudocompounds (e.g., *hammock*, which does not contain the lexemes *ham* and *mock*). These words could be preceded by the brief presentation (57 ms) of either the first constituent (e.g., *book*, *jay*, or *ham*), the second constituent (e.g., *shop*, *walk*, or *mock*), or an unrelated word. Shoolman and Andrews found that in a normal context condition[2] similar priming was observed for the initial and for the final constituents, in both cases facilitative with respect to the unrelated priming condition. These results were interpreted in terms of a parallel activation of separate representations of the morphemic constituents. However, a serial component of processing has been also proposed for compound word recognition. This serial processing account is related to "a verification process conducted to evaluate the legitimacy of the combination of constituent morphemes" (Shoolman & Andrews, 2003, p. 272). This proposal of serial processing is in line with evidence from eye movement studies, which shows that there is serial activation and processing

[2] The authors also included a biased context condition, as well as the unbiased context condition. In the biased context condition, all nonwords in the lexical decision task were formed by combining two existing words (e.g., *startstop*, *budrose*). We will only refer to the unbiased context condition, since the manipulation we used in the present study did not include a biased context condition.

of the compound words (e.g., Andrews et al., 2004; Juhasz et al., 2003; Pollatsek, Hyönä, & Bertram, 2000). Readers access the first constituent first, and subsequently access the second one, in a serial fashion. Therefore, one could argue that a greater priming effect should be obtained for the first constituent (e.g., *milk-MILKMAN*) as compared to the second one (e.g., *man-MILKMAN*). There is, in fact, evidence showing that lexical access of long polymorphemic words seems to be performed in a serial manner (Bertram & Hyönä, 2003; Niswander-Klement & Pollatsek, 2006). However, this length criterion makes it difficult to compare results coming from masked and unmasked priming experiments (showing parallel access to constituents) and eye movement studies (typically showing serial access to constituents), since most of the compound words that have been used in the priming experiments are shorter than words that have been used in eye movement studies. We will come back to this issue in the General Discussion.

The aim of the present experiments is twofold. On the one hand, we want to examine whether constituent priming effects can be obtained between compound words (will *postman* activate *MILKMAN*? and will *postman* activate *MANKIND*?). Obtaining such an effect under masked priming conditions would reflect fast, early, strong morphological decomposition, in line with the prelexical decomposition account (Duñabeitia, Perea, & Carreiras, 2007a; Rastle et al., 2000, 2004). We also want to examine whether priming effects can be modulated as a function of the position of the shared constituent (will *postman* prime *MILKMAN* the same as *milkshake* does?), which is a very relevant question for the parallel versus serial processing issue. Not all languages permit such an extreme manipulation, since compounding is not equally productive in all languages. Languages such as Basque or Finnish provide a good opportunity to test this, since compounding in these languages is a frequent morphological mechanism for novel word creation, and compounds sharing the same constituent can easily be found. In fact, in Basque, one can find two compound words that share the same constituent but in a different lexeme position (i.e., the first constituent in one compound appears as the second constituent in another compound; e.g., *mendikate* [mountain range: *mendi* (mountain) + *kate* (chain)] and *sumendi* [volcano: *su* (fire) + *mendi* (mountain)]). On the other hand, we wanted to test if the coactivation of *postman* and *milkman* or *milkman* and *milkshake* is the consequence of a morphological decomposition process, or if, on the contrary, it is a reflection of orthographic form overlap.

In Experiment 1, participants were presented with compound words in a masked priming lexical decision task. These compound words could be briefly preceded by another compound word that shared either the initial constituent (e.g., *lanordu-LANPOSTU*), or the final one (e.g., *bainugela-EGONGELA*), or by a noncompound word with no shared units (e.g., *janari-LANPOSTU* or *nabaritu-EGONGELA*). If morphological decomposition already occurs at a prelexical stage of lexical access, then some facilitation effects for the morphologically related conditions is expected (i.e., the conditions in which primes and targets are compound words). We also wanted to assess whether these facilitation effects could be modulated by the position of the shared constituent, as predicted by models in compound word processing from eye movement studies: a greater priming effect for compounds sharing the first/initial constituent than for those sharing the second/final one (see Hyönä, Pollatsek, & Bertram, 2005).

In Experiment 2, we employed a more extreme manipulation: Participants were presented with compound words that were briefly preceded by another compound word that shared one constituent but in the other location, as in *mendikate-SUMENDI* (*mendi* "mountain", *kate* "chain", and *su* "fire"). If we find a priming effect under such extreme conditions, this would imply that the visual word recognition system identifies elements (in a manner) irrespective of position. It would also imply that the cognitive system, and more specifically the parsing system, processes the two constituents very fast (i.e., apparently at an early stage of visual word recognition), and that the constituents are accessed independently of their location in the string, allowing cross-word position-independent activation.

Finally, in Experiment 3, we examined the viability of an account based on orthographic form overlap rather than morphological similarity. More specifically, we tested whether masked priming effects can be obtained when the prime and the target share grapheme chunks that do not constitute morphemes (e.g., *arrantza-ARRISKU*, fishing-DANGER, or *molekula-PELIKULA*, molecule-FILM).

EXPERIMENT 1

Method

Participants. A total of 30 native Basque speakers took part in the experiment. They were students at the University of the Basque Country. They received €3 in exchange for their collaboration.

Materials. A set of 52 compound words was selected from the Basque E-Hitz database (Perea et al., 2006; see Appendix for a complete list of materials). The mean frequency of these words was of 19.77 appearances per million (range: 0.28–180.29), and the mean length was of 8.2 letters (range: 7–11). These compound words could be perfectly decomposed into their two forming lexemes (e.g., *lanpostu*, workplace, can be decomposed into *lan*[work] + *postu*[place]). The overall frequency and length of each of the two constituents was also controlled: a mean frequency of 527.6 for the first constituents and a mean frequency of 534.3 for the second constituents; a mean length of 4.0 for the first constituents and a mean length of 4.2 for the second constituents. These compounds were divided into two subsets of similar characteristics (see Table 1). The first subset of words was formed by 26 compound words that served as targets (e.g., *LANPOSTU*), and that were primed either by 26 other compounds sharing only the first constituent (e.g., *lanordu*, [*lan* + *ordu*], working hour), or by 26 noncompound words with no orthographic/semantic overlap with the targets (e.g., *janari*, food). The targets and primes from this subset were matched as closely as possible in frequency and length. The frequency and length of the constituents of the targets and of the compound primes were also matched. Since the first constituent was the one repeated, the mean frequency and length was exactly the same (598.06 appearances per million and 4.0 letters). The word-final constituents had a mean frequency of 485.07 in the targets and of 437.36 in the primes. The second subset of words was formed by the other 26 compound words, which served as targets (e.g., *EGONGELA*, living room [*egon* + *gela* = to be + room]). These could be preceded by another different group of 26 compound prime words sharing only the second constituent (e.g., *bainugela*, bathroom [*bainu* + *gela* = bath + room]), or by 26 new noncompound words (e.g., *nabaritu*, to notice). Targets and primes from this subset were also matched in frequency and length and with respect to the conditions in the previous subset. The frequency and length of the constituents of the targets and of the compound primes were also matched. The first constituents of the targets had a mean frequency of 457.15, and the mean frequency of the compound primes was 320.09. In both conditions, the mean frequency of the second constituents was 583.62 and their length was of 3.9 letters. Overall, the letters shared between primes and targets in all the related

TABLE 1
Mean word frequency (per million), length (in number of letters), and constituent frequency (per million) of the words used in Experiment 1

	Frequency	*Length*	*1st constituent frequency*	*2nd constituent frequency*
1st constituent shared				
Compound primes	21.10	8.46	598.06	437.36
Noncompound primes	17.56	8.46	—	—
Compound targets	19.28	8.46	598.06	485.07
2nd constituent shared				
Compound primes	18.55	7.85	320.09	583.62
Noncompound primes	17.79	7.85	—	—
Compound targets	20.26	8.04	457.15	583.62

conditions made up 47.5% of the characters of the words. A transparency norming survey was conducted for all the compound words that were used in the present experiment as primes or targets. Fourteen Basque native speakers rated these words on a 1–7 Likert scale (with lower values corresponding to opaque compound words and higher values to transparent compound words). On average, all the compound words were rated as transparent, with an overall rating of 5.6 ($\pm$1.1). In order to make the lexical decision possible, a set of 52 pseudowords was included as targets, created by replacing some letters from the target words (e.g., *LENPUSDO* from *LANPOSTU* and *AJUNJALE* from *EGONGELA*). The mean number of letters that were replaced from the base words was 4.7 (standard deviation = 1.3), ensuring enough replacements so that long-term priming effects within the list of materials could not be expected from the nonwords to their base words. These nonwords could be preceded by other nonwords sharing the same initial/final letters (e.g., *lenurto*, *beinojale*) or by other nonwords with no orthographic similarity at all (e.g., *prunsutie*). Two lists of materials were created, so that each target appeared once in each, but each time in a different priming condition (related or unrelated). Different participants were assigned to each of the lists.

Procedure. Participants were individually tested in a well-lit sound-proofed room. The presentation of the stimuli and recording of the responses was carried out using DMDX software (Forster & Forster, 2003) on a PC-compatible computer associated to a CRT monitor. Each trial consisted in the presentation of a forward mask created by hash-mark symbols for 500 ms, followed by the display of the prime for 66 ms (four cycles of 16.6 ms each), and immediately followed by the presentation of the target. We used an SOA of 66 ms because previous experiments with Basque polymorphemic words have also employed this exposure time, since words in Basque tend to be very long (see also Duñabeitia et al., 2007a). Participants were not informed of the presence of lowercase items. Although the SOA employed may be bordering on conscious processing, participants reported no awareness of the prime stimuli when asked after the experiment. Primes were presented in lowercase and targets in uppercase, both in 12 pt. Courier New font. Target items remained on the screen for 2500 ms or until a response was given. Participants were instructed to press the “M” key on the keyboard when the displayed item was a real Basque word, and the “Z” key when it was not. They were told to do so as fast and as accurately as possible. Twelve practice trials (six words and six nonwords) were used for warm-up purposes. All the items were randomly presented in order to avoid order repetition effects across participants.

Results and discussion

Reaction times below 250 ms or above 1500 ms and reaction times associated with incorrect responses were not included in the latency analyses. Response times and error rates associated to each experimental condition are displayed in Table 2. Separate analyses of variance (ANOVAs) treating participants and items as random factors (*F*1 and *F*2, respectively) were conducted based on a 2 (shared constituent: first, second) $\times$ 2 (type of prime: related, unrelated) $\times$ 2 (list: List 1, List 2) design. List was included as a dummy variable to extract the error variance due to the counterbalancing lists.

Word data. Compound words preceded by a related compound word that shared either the first or the second constituent were recognised faster than those preceded by an unrelated control word (39 ms faster), $F1(1, 28) = 26.67$, $p < .01$; $F2(1, 48) = 32.40$, $p < .01$. No other effects or interactions were significant (all *F*s < .40 and all *p*s > .50). This indicates that compound words preceded by other compounds that shared the same initial or final constituents exerted a facilitation that did not differ significantly regarding the position of the shared constituent (41 and 36 ms, respectively).

The ANOVAs on the error rates only showed a marginally significant trend indicating that compound words that shared the second constituent were recognised more accurately than compound words that shared the first constituent, $F1(1, 28) = 12.10$, $p < .01$; $F2(1, 48) = 3.33$, $p = .07$.

Nonword data. No reliable effects were found in the response times to nonwords (all *F*s < 2 and all *p*s > .15). The ANOVAs on the error rates only showed that nonwords that could share the first part of the string with others were read less accurately, although this effect was only significant in

TABLE 2
Mean lexical decision times (in ms) and percentage of errors (in parentheses) for word and nonword targets in Experiment 1

	Type of prime		
	Related	*Unrelated*	*Priming*
Words			
1st constituent shared	735 (4.6)	777 (4.9)	42 (0.3)
2nd constituent shared	744 (1.5)	780 (2.3)	36 (0.8)
Nonwords			
Initial part shared	848 (4.6)	851 (5.9)	3 (1.3)
Final part shared	840 (3.8)	838 (1.3)	−2 (−2.5)

the analysis by participants, $F1(1, 28) = 5.91$, $p < .03$; $F2(1, 48) = 3.02$, $p = .09$.

The results from Experiment 1 were clearcut: Compound words that share one of the constituents do activate each other (e.g., *lanordu-LANPOSTU*), and this is so independently of the position of the shared constituents. This is an important finding that provides a step forward in the study of morphological priming. Until now, studies dealing with compound words and constituent priming have always presented constituents in isolation (e.g., *book-BOOKSHOP*; Shoolman & Andrews, 2003). Here we demonstrate that automatic unconscious access to the constituents can also be achieved when these constituents are presented in a different compound word (e.g., *bookmark-BOOKSHOP*).

Thus, our results provide strong evidence in favour of early morphological decomposition by showing that the visual word recognition system automatically establishes a relationship between two words that share one morphological constituent without regard to its position. However, for this assumption to be plausible, other explanations based on nonmorphological relationships have to be ruled out. For instance, one could argue that the priming effect obtained from *book-BOOKSHOP* (or from *bookmark-BOOKSHOP*) reflects a purely form-based orthographic priming effect based on the letters shared between prime and target, rather than a morphologically based priming effect. In the following two experiments we will test this possibility directly. To this end, in Experiment 2 we used pairs of compound words that share a constituent, but in a different position (e.g., *milkman-MANKIND*). Considering the results from Experiment 1, we expect some activation between the two compound words as compared to an unrelated, control condition. To our knowledge, no such effect has been shown in the orthographic priming literature (e.g., *chocolate-LATENCY*), and hence, a priming effect under these conditions would pose serious problems for a "form overlap" account (note that the shared units in Experiment 2 do not share location in the strings).

EXPERIMENT 2

Method

Participants. A different group of 34 native speakers of Basque from the University of the Basque Country (UPV/EHU) took part in this experiment.

Materials. Two sets of 24 Basque compound words were selected. The two sets were of similar characteristics in terms of word frequency and length (see Table 3). The first group of words (e.g., *mendikate*, mountain range, *mendi* [mountain] + *kate* [chain]) had a mean frequency of 24.20 (range: 0.28–326.89)

TABLE 3
Mean word frequency (per million), length (in number of letters), and constituent frequency and length of the words used in Experiment 2

	Whole word		*1st constituent*		*2nd constituent*	
	Frequency	*Length*	*Frequency*	*Length*	*Frequency*	*Length*
Compounds (*mendikate*)	24.20	8.9	812.65	4.2	407.64	4.7
Controls	24.64	8.9	—	—	—	—
Compounds (*sumendi*)	26.96	8.4	445.33	4.2	812.65	4.2
Controls	27.90	8.1	—	—	—	—

and a mean number of 8.9 letters (range: 7–12). The second group of compound words was formed so that the second constituent was the same as the first constituent in the first group of compound words (e.g., *sumendi* [volcano], *su* [fire] + *mendi* [mountain]). All these words and the constituents were matched as closely as possible in frequency and length. We created two experimental blocks in order to maximise the possibility of obtaining an effect. In the first block, compound words (e.g., *SUMENDI*) could be briefly preceded by other compound words that had their second lexeme in initial position (e.g., *mendikate*), or by an unrelated word (e.g., *laguntza*, help). The unrelated items were matched to the related words as closely as possible in terms of word frequency and length (see Table 3). In the second block, the order of the prime–target presentation was reversed, and primes in the first block acted as targets now, including a new set of unrelated items (e.g., *sumendi-MENDIKATE* vs. *panorama-MENDIKATE*). To avoid any potential influence of block presentation order, the block sequence was randomised for all the participants. We also included a set of 48 nonwords. The same priming conditions as for the words were kept for the nonwords (e.g., *artioka-GEOARTI* vs. *perideda-GEOARTI*). Primes and targets in the related conditions of the two blocks shared on average 48.5% of the letters (note that the overlap is very similar to that in Experiment 1). The same 14 Basque speakers who completed the transparency norming survey for compound words in Experiment 1 were presented with a similar questionnaire for all these compound words. The mean transparency value in the 1–7 scale was 5.6 (± 0.9), showing that the compound words were on average highly transparent.

Procedure. This was the same as in Experiment 1.

Results and discussion

Incorrect responses and response latencies beyond or above the cutoff values (250 and 1500 ms) were excluded from the latency analyses. Mean reaction times and percentages of error per condition are presented in Table 4. ANOVAs were conducted based on a 2 (relatedness: related, unrelated) × 2 (list: 1, 2) design.

Word data. Compound words preceded by other compound words sharing one constituent were recognised faster (20 ms faster) than when preceded by unrelated prime words, $F1(1, 32) = 6.82$, $p < .02$; $F2(1, 46) = 3.19$, $p = .08$. ANOVAs on the error rated did not show any reliable effects (all Fs < 1).

Nonword data. None of the differences were significant in the latency analyses or in the error rate analyses (all Fs < 1 and ps > .50).

Results from Experiment 2 revealed that it is possible to obtain cross-lexeme masked morphological priming effects in compound words (e.g., *milkman-MANKIND*). These results provide a strong piece of evidence in favour of an early morphological decomposition mechanism. It should be noted, however, that the priming effects were marginally significant in the analysis by items. Taking into account that it is not easy to find this type of word pairs, and due to the scarce number of potential items (which forced us to repeat the primes as targets in different blocks), further research is needed in order to assess the stability of these results.

As stated in the introduction, morphological units seem to be responsible for the appearance of priming effects between words that share a morpheme. This has been shown for derived words sharing an affix (e.g., *darkness-HAPPINESS*; Duñabeitia, Perea, & Carreiras, in press; Marslen-Wilson et al., 1996; Reid & Marslen-Wilson, 2000). In Experiments 1–2, we have shown a similar pattern for compound words sharing a constituent lexeme (e.g., *postman-MILKMAN*). However, it is not entirely clear whether the results from Experiments 1 and 2 could be merely reflecting an orthographic priming effect rather than a morphological priming effect, or whether orthography is a confound that, together with morphological overlap, makes these types of effects more salient. Although there is some evidence showing

TABLE 4
Mean lexical decision times (in ms) and percentage of errors (in parentheses) for word and nonword targets in Experiment 2

	Type of prime		
	Related	*Unrelated*	*Priming*
Words	867 (4.4)	887 (4.4)	20 (0.0)
Nonwords	983 (6.9)	968 (7.2)	−15 (0.3)

that this is not the case (e.g., Chateau et al., 2002), other authors have presented evidence supporting this view (e.g., Forster & Azuma, 2000). For this reason, we conducted a new experiment testing uniquely orthographic priming. In Experiment 3, we mimicked the conditions from Experiment 1 without using compound words (thus, the overlap between prime and target strings was orthographic in nature). Hence, noncompound Basque words could be preceded by other noncompound words sharing some of the initial or ending letters (e.g., *arrantza-ARRISKU*) or by an orthographically unrelated word (e.g., *merkatu-ARRISKU*). We also included an identity condition in this experiment (e.g., *arrisku-ARRISKU*); as it is important to include a condition that has ubiquitously shown a priming effect. If the findings from Experiment 3 reveal identity priming effects for pairs like *arrisku-ARRISKU*, and no signs of a priming effect for pairs sharing some of the beginning or ending letters (like in *arrantza-ARRISKU*), then the results from Experiments 1 and 2 would be better understood in terms of a purely morphological priming effect, rather than a mixed effect resulting from the morpho-orthographic confound. In contrast, if the results in Experiment 3 mimic those in Experiment 1, this would reinforce a form-based explanation for these findings.

EXPERIMENT 3

Method

Participants. A different group of 33 native speakers of Basque from the University of the Basque Country (UPV/EHU) took part in this experiment.

Materials. A set of 66 noncompound Basque words was selected from the Basque database (Perea et al., 2006). These words were divided into two

TABLE 5
Mean word frequency (per million) and length (in number of letters) of the words used in Experiment 3

	Frequency	*Length*
Beginning part shared		
Related primes	39.39	7.2
Unrelated primes	34.11	7.5
Targets	35.71	7.5
Ending part shared		
Related primes	31.71	7.6
Unrelated primes	30.51	7.6
Targets	37.46	7.6

subsets of similar characteristics (see Table 5). The first subset of words was formed by 33 words that served as targets (e.g., *ARRISKU*, danger), and that could be briefly preceded by themselves (i.e., identity condition), by 33 other words that shared the beginning of the word (e.g., *arrantza*, fishing), or by 33 words with no orthographic overlap with the targets (e.g., *merkatu*, market). The targets and primes from this subset were matched as closely as possible in frequency and length. The second subset of words was formed by the other 33 noncompound words, which served as targets (e.g., *PELIKULA*, film). These words could be preceded by themselves (i.e., identity condition), by another different group of 33 words sharing with them the final part of the word (e.g., *molekula*, molecule), or by 33 new unrelated words (e.g., *ministro*, minister). Targets and primes from this subset were also matched in frequency and length and with the conditions in the previous subset. The amount of shared letters in these two subsets of words was 42%. In order to make the lexical decision possible, a set of 66 nonwords was also included. Three lists of materials were created, so that each target appeared once in each, but each time in a different priming condition (identity, related, or unrelated). Different participants were assigned to each of the lists.

Procedure. This was the same as in Experiment 1.

Results and discussion

Incorrect responses and response latencies below 250 ms or above 1500 ms were not included in the latency data analyses. Mean reaction times and percentages of error are presented in Table 6. ANOVAs for participants and items were conducted based on a 2 (shared part: beginning, ending) × 3 (type of prime: identity, related, unrelated) × 3 (list: 1, 2, 3) design. Tests of simple

TABLE 6
Mean lexical decision times (in ms) and percentage of errors (in parentheses) for word and nonword targets in Experiment 3

	Type of prime			*Priming*	
	Identity	*Related*	*Unrelated*	*Unrelated–related*	*Unrelated–identity*
Words					
Beginning part shared	716 (1.9)	793 (1.9)	781 (1.9)	−12 (0.0)	65 (0.0)
Ending part shared	730 (0.6)	775 (1.9)	795 (3.9)	20 (2.0)	65 (2.3)
Nonwords					
Beginning part shared	864 (3.9)	901 (2.8)	906 (2.8)	5 (0.0)	42 (−1.1)
Ending part shared	903 (4.7)	921 (2.5)	908 (5.0)	−13 (2.5)	5 (0.3)

effects were also conducted in order to assess statistical differences between the critical priming conditions, depending on the type of prime.

Word data. The type of prime had a significant impact on the reaction times, $F1(1, 30) = 63.94$, $p < .001$; $F2(1, 60) = 22.26$, $p < .001$. The position of the shared chunk and the interaction between the two factors were not significant (all Fs < 1 and all ps > .65). Pairwise comparisons were performed in order to assess the impact of each type of prime. Words preceded by an identity prime were recognised substantially faster than words preceded by an unrelated prime (65 ms), $F1(1, 30) = 63.94$, $p < .001$; $F2(1, 63) = 22.49$, $p < .001$, or by an orthographically related prime (61 ms), $F1(1, 30) = 80.13$, $p < .001$; $F2(1, 63) = 18.08$, $p < .001$. Crucially, the critical comparison between priming effects in the related and unrelated conditions did not show any significant differences: Reaction times to words preceded by orthographically related and unrelated primes did not differ (a negligible 4 ms difference; both Fs < 1 and ps > .65). None of the interactions of these pairwise effects with the position of the shared part was significant (all ps > .10).

The ANOVAs on the error rates showed a main effect of type of prime, $F1(1, 30) = 3.19$, $p = .08$; $F2(1, 60) = 4.80$, $p < .04$. The main effect of position of the shared part was not significant (both Fs < 1 and ps > .75). The interaction between the two factors was significant, $F1(1, 30) = 4.44$, $p < .05$; $F2(1, 60) = 4.80$, $p < .04$. Pairwise comparisons were carried out for each type of prime in each of the positions. For the group of words in the shared ending condition, words in the identity condition were recognised more accurately than words preceded by an unrelated word, $F1(1, 30) = 8.47$, $p < .01$; $F2(1, 30) = 6.10$, $p < .02$. The rest of the pairwise comparisons did not reach significance (all Fs < 2.30 and all ps > .13).

Nonword data. The main effect of shared part was only significant in the analysis by participants, $F1(1, 30) = 4.40$, $p < .05$; $F2(1, 60) = 2.49$, $p = .12$. The main effect of type of prime was significant, $F1(1, 30) = 4.22$, $p < .05$; $F2(1, 60) = 4.13$, $p < .05$. The interaction between the two factors was only significant in the analysis by participants, $F1(1, 30) = 6.42$, $p < .02$; $F2(1, 60) = 1.81$, $p > .18$. Tests of simple effects were conducted to assess the differences between the three priming conditions. Nonwords in the identity condition were recognised faster (23 ms) than nonwords in the unrelated condition, $F1(1, 30) = 4.22$, $p < .05$; $F2(1, 63) = 4.14$, $p < .05$, and faster (27 ms) than nonwords in the related condition, $F1(1, 30) = 8.39$, $p < .01$; $F2(1, 63) = 3.49$, $p = .07$. Responses to nonwords in the related and unrelated conditions did not differ significantly (both Fs < 1 and ps > .60). The interaction of these pairwise comparisons with position of the shared part did not reach significance (ps > .30).

ANOVAs on the error rates did not show any reliable effects (all Fs < 1.10 and ps > .32).

The results from Experiment 3 were clear: Under masked priming conditions, two words sharing a part of the string that does not constitute a lexeme do not reliably activate each other—we also showed that these target words yielded robust masked repetition priming. Hence, in the light of these results, we can conclude that the results obtained in Experiments 1 and 2 are not reflecting masked orthographic priming, but masked morphological priming (or masked constituent priming).

GENERAL DISCUSSION

These results provide empirical evidence that morphological priming across transparent compound words occurs: Two transparent compound words that share a constituent automatically activate each other. Importantly, this effect is similar in size for word initial and word final constituents (Experiment 1). Furthermore, this morphological priming effect also occurs when the shared constituent does not occupy the same position for prime and target (e.g., a word initial constituent in the prime activates a target where the constituent is word-final; Experiment 2). Finally, what we should also note is that these morphological priming effects do not seem to be a consequence of orthographic form overlap: no signs of masked orthographic priming effects were found for words sharing some initial or ending letters of the string (Experiment 3).

As indicated in the Introduction, recent evidence from a constituent masked priming experiment has shown that a compound word that follows the brief presentation of one of its constituents is recognised faster than when it follows the presentation of an unrelated word (e.g., *man*-*MILKMAN* and *milk*-*MILKMAN* faster than *pen*-*MILKMAN*; see Shoolman & Andrews, 2003). The present results replicate and extend this finding by exploiting a more extreme manipulation, revealing that facilitative priming can also be obtained across compound words (e.g., *postman*-*MILKMAN* and *mankind*-*MILKMAN*). These results converge with previous evidence from long-lag priming experiments, which show that it is not only the preview of constituents that facilitates the recognition of compounds, but that the reverse manipulation also produces significant effects (e.g., *milkman*-*MILK*; see Jarema et al., 1999; Libben et al., 2003; Monsell, 1985; Zwitserlood, 1994). Furthermore, the same pattern of results has also been obtained when the preview involves a semantic associate of one of the constituents (e.g., *woman*-*MILKMAN*; Sandra, 1990).

We hypothesised in the introduction that, according to previous evidence from eyetracking experiments in compound word processing (Andrews et al., 2004; Juhasz et al., 2003), a stronger facilitative priming effect would be expected for compounds sharing the first constituent than for compounds sharing the second. This hypothesis was based on results indicating a relatively serial processing that means that frequency effects from the first constituent lexeme arise earlier than effects from the second constituent (which tends to overlap with whole-word effects). Many eye-movement and reaction time studies have shown that the first constituent has a processing advantage (e.g., Hyönä, Bertram, & Pollatsek, 2004; Hyönä & Pollatsek, 1998; Pollatsek & Hyönä, 2005; Pollatsek et al., 2000), and that the constituents of the compound word are processed sequentially (Hyönä, Pollatsek, & Bertram, 2005). However, and consistently with previous priming experiments, we did not find any differences for the two constituents. It is not clear to us what the reason for this apparent discrepancy is. One possibility is that priming paradigms and online reading tasks provide insights to different processes; for instance, in an online reading task, the reader has a parafoveal advantage for the initial constituent when the eye is fixated on word *n*–1, whereas in the masked priming paradigm, the two constituents are presented at the same time and foveally—note that in a split-fovea framework (Shillcock, Ellison, & Monaghan, 2000), the second constituent in a masked priming paradigm is initially processed by the (more efficient) left hemisphere (see, e.g., Perea, Acha, & Fraga, 2008a, for evidence with a divided field paradigm). Besides, there is evidence showing that processing of polymorphemic words only becomes serial when these words constitute long strings (e.g., Bertram & Hyönä, 2003; see Niswander-Klement & Pollatsek, 2006, for evidence on how whole-word length affects the way in which polymorphemic words are decomposed and processed), since the eye tends to carry out more than a single fixation on the whole word. In the present experiments, it is possible that subjects captured words with a single eye fixation, because the words were relatively short (approximately eight characters), and were presented in the centre of the screen.[3] Even though a priori the present data are consistent with the parallel processing view, it should be noted that lexical decision task is not the best method to tap into the time course of processing, since the information gathered refers to a postdecisional stage. Thus, serial processing cannot entirely be ruled out and further research is needed in order to explore this issue with different paradigms.

Grainger et al. (2006) found that masked orthographic priming emerged when words were preceded by the initial or final part of the string (always nonwords; e.g., *diffe-DIFFERENT* and *erent-DIFFERENT*). This finding may seem to be in conflict with our findings in Experiment 3. However, what

[3] We thank an anonymous reviewer for pointing this out.

we should note here is that in Experiment 3 we used words as primes, whereas Grainger et al. used nonwords as primes. As indicated earlier, similar manipulations using real words as primes (e.g., *shallow-FOLLOW*), have yielded inconclusive results (Forster & Azuma, 2000, and Giraudo & Grainger, 2003 vs. Chateau et al., 2002, and Duñabeitia et al., in press). For instance, Duñabeitia et al. showed that it is possible to obtain masked affix priming effects between pairs like *baker-WALKER*, while they failed to obtain any signs of masked form priming between pairs like *hotel-BROTHEL* (see also Reid & Marslen-Wilson, 2000, for a cross-modal priming study). Thus, the differences between the null form priming effects in Experiment 3 and other preceding significant orthographic effects (e.g., Forster & Azuma, 2000; Giraudo & Grainger, 2003) may well rely on the amount of letters that were shared between primes and targets. For instance, Forster and Azuma used word pairs that shared 66% of the letters. In the present experiment, the percentage of shared letters was lower (42%) and this could be a substantial difference that could have resulted in an orthographic priming effect in their experiment, and in the lack of such an effect in our study.[4] It is worthy of note that the amount of characters shared was very similar in all three experiments (47.5%, 48.5%, and 42%, respectively), and therefore the differences between the results in Experiments 1–2 and those in Experiment 3 cannot be easily accounted for by any explanation based on the degree of overlap. Instead, the most parsimonious account for the differences in Experiments 1–2 vs. Experiment 3 is in terms of morphological versus form-based effects.

As stated earlier, our interpretation of the present results relies on early morphological decomposition. However, one could argue that the presence of relatively long response times may also reflect some late effects due to the morphological decomposition of the prime. Of course, the prime stimulus is still being processed after prime offset—if not, there would be no explanation for masked translation and associative priming effects (e.g., Perea, Duñabeitia, & Carreiras, 2008b). But the point here is that the participants reported no knowledge of the primes, and the only difference between the conditions was the prime–target relationship. Hence, the most parsimonious explanation is that the information from the prime helped in processing the target word. Given that the target words were long and of low frequency, the decision mechanism in the lexical decision task was noisy (e.g., in a diffusion model account; Ratcliff, Gomez, & McKoon, 2004; see

[4] Note that this was also the case in the study by Duñabeitia et al. (in press), where they used strings that shared approximately 40% of the letters, and note that Giraudo and Grainger (2003) also failed to obtain significant masked form priming effects between words when the words shared approximately 40% of the letters (their significant form priming effect came from strings that shared at least 55% of the letters).

also Gómez, Ratcliff, & Perea, 2007), and hence response times were on average relatively long. Importantly, response time distributions for the related and unrelated conditions in a masked priming procedure tend to show a shift and not a change in shape (e.g., Pollatsek, Perea, & Carreiras, 2005). This is consistent with the idea that the differences between the conditions do not arise at the decision level—note that differences at the decision level would imply a different shape of the underlying response time distribution in a diffusion-like model (e.g., see Ratcliff et al., 2004). Nonetheless, we agree that lexical decision times may not be the best method to tap into the time course of processing, since they give the researcher only one data point at the end of processing. One more direct way to test the early/late role of morphological decomposition is to use a dependent variable with detailed time resolution, such as ERP waves, in conjunction with the lexical decision task. In this light, we should note that Lavric, Clapp, and Rastle (2007) reported that morphological decomposition in a masked priming lexical decision task takes places at early time windows in the ERP waves (and in lexical decision times).

In sum, the present study provides compelling evidence for early morphological decomposition of compound words, via a constituent masked priming paradigm. We have shown that both constituents of a compound word are accessed early in visual word recognition, and that morphological priming is obtained independently of the position of the shared morpheme (*postman* activates *MILKMAN* to the same degree as *milkshake* does). Taken together, the present findings pose some important constraints for future development of models of morphological processing and lexical access.

Original manuscript received June 2007
Manuscript accepted February 2008
First published online month/year

REFERENCES

Andrews, S. (1986). Morphological influences on lexical access: Lexical or nonlexical effects. *Journal of Memory and Language*, *25*, 726–740.

Andrews, S., Miller, B., & Rayner, K. (2004). Eye movements and morphological segmentation of compound words: There is a mouse in mousetrap. *European Journal Cognitive Psychology*, *16*, 285–311.

Bertram, R., & Hyönä, J. (2003). The length of a complex word modifies the role of morphological structure: Evidence from eye movements when reading short and long Finnish compounds. *Journal of Memory and Language*, *48*, 615–634.

Chateau, D., Knudsen, E. V., & Jared, D. (2002). Masked priming of prefixes and the influence of spelling–meaning consistency. *Brain and Language*, *81*, 587–600.

Devlin, J. T., Jamison, H. L., Matthews, P. M., & Gonnerman, L. M. (2004). Morphology and the internal structure of words. *Proceedings of the National Academy of Sciences*, *101*(41), 14984–14988.

Diependaele, K., Sandra, D., & Grainger, J. (2005). Masked cross-modal morphological priming: Unravelling morpho-orthographic and morpho-semantic influences in early word recognition. *Language and Cognitive Processes*, *20*, 75–114.

Domínguez, A., Segui, J., & Cuetos, F. (2002). The time-course of inflexional morphological priming. *Linguistics*, *40*, 235–259.

Duñabeitia, J. A., Marín, A., Avilés, A., Perea, M., & Carreiras, M. (2008). Constituent priming effects in young and older adults: Evidence for preserved morphological processing in healthy elderly readers. *Manuscript submitted for publication*.

Duñabeitia, J. A., Perea, M., & Carreiras, M. (2007a). Do transposed-letter similarity effects occur at a morpheme level? Evidence for morpho-orthographic decomposition. *Cognition*, *105*, 691–703.

Duñabeitia, J. A., Perea, M., & Carreiras, M. (2007b). The role of the frequency of constituents in compound words: Evidence from Basque and Spanish. *Psychonomic Bulletin and Review*, *14*, 1171–1176.

Duñabeitia, J. A., Perea, M., & Carreiras, M. (in press). Does darkness lead to happiness? Masked suffix priming effects. *Language and Cognitive Processes.*

Feldman, L. B. (2000). Are morphological effects distinguishable from the effects of shared meaning and shared form? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*, 1431–1444.

Feldman, L. B., & Prostko, B. (2002). Graded aspects of morphological processing: Task and processing time. *Brain and Language*, *81*, 12–27.

Feldman, L. B., & Soltano, E. G. (1999). Morphological priming: The role of prime duration, semantic transparency and affix position. *Brain and Language*, *60*, 33–39.

Forster, K. I., & Azuma, T. (2000). Masked priming for prefixed words with bound stems: Does submit prime permit? *Language and Cognitive Processes*, *15*, 539–561.

Forster, K. I., & Davis, C. (1984). Repetition priming and frequency attenuation in lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *10*, 680–698.

Forster, K. I., & Forster, J. C. (2003). DMDX: A Windows display program with millisecond accuracy. *Behavior Research Methods, Instruments, and Computers*, *35*, 116–124.

Giraudo, H., & Grainger, J. (2001). Priming complex words: Evidence for supralexical representation of morphology. *Psychonomic Bulletin and Review*, *8*, 96–101.

Giraudo, H., & Grainger, J. (2003). On the role of derivational affixes in recognizing complex words: Evidence from masked priming. In R. H. Baayen & R. Schreuder (Eds.), *Morphological structure in language processing* (pp. 209–232). Berlin: Mouton de Gruyter.

Gómez, P., Ratcliff, R., & Perea, M. (2007). A model of the go/no-go task. *Journal of Experimental Psychology: General*, *136*, 389–413.

Grainger, J., Granier, J. P., Farioli, F., van Assche, E., & van Heuven, W. (2006). Letter position information and printed word perception: The relative-position priming constraint. *Journal of Experimental Psychology: Human Perception and Performance*, *32*(4), 865–884.

Hyönä, J., Bertram, R., & Pollatsek, A. (2004). Are long compound words identified serially via their constituents? Evidence from an eye-movement contingent display change study. *Memory and Cognition*, *32*, 523–532.

Hyönä, J., & Pollatsek, A. (1998). Reading Finnish compound words: Eye fixations are affected by component morphemes. *Journal of Experimental Psychology: Human Perception and Performance*, *24*, 1612–1627.

Hyönä, J., Pollatsek, A., & Bertram, R. (2005). Identifying compound words in reading: An overview and a model. In G. Underwoord (Ed.), *Cognitive processes in eye guidance* (pp. 79–103). Oxford, UK: Oxford University Press.

Isel, F., Gunter, T. C., & Friederici, A. D. (2003). Prosody-assisted head-driven access to spoken German compounds. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *29*, 277–288.

Jacoby, L. L. (1983). Remembering the data: Analyzing interactive processes in reading. *Journal of Verbal Learning and Verbal Behaviour*, *22*, 485–508.

Jarema, G., Busson, C., Nikolova, R., Tsapkini, K., & Libben, G. (1999). Processing compounds: A cross-linguistic study. *Brain and Language*, *68*, 362–369.

Juhasz, B., Starr, M., Inhoff, A. W., & Placke, L. (2003). The effects of morphology on the processing of compound words: Evidence from naming, lexical decisions, and eye fixations. *British Journal of Psychology*, *94*, 223–244.

Lavric, A., Clapp, A., & Rastle, K. (2007). ERP evidence of morphological analysis from orthography: A masked priming study. *Journal of Cognitive Neuroscience*, *19*, 866–877.

Libben, G., Gibson, M., Yoon, Y.-B., & Sandra, D. (2003). Compound fracture: The role of semantic transparency and morphological headedness. *Brain and Language*, *84*, 26–43.

Longtin, C. M., Segui, J., & Hallé, P. A. (2003). Morphological priming without morphological relationship. *Language and Cognitive Processes*, *18*, 313–334.

Marslen-Wilson, W., Tyler, L. K., Waksler, R., & Older, L. (1994). Morphology and meaning in the English mental lexicon. *Psychological Review*, *101*, 3–33.

Marslen-Wilson, W. D., Ford, M., Older, L., & Zhou, X. (1996). The combinatorial lexicon: Priming derivational affixes. In *Proceedings of the 18th annual conference of the Cognitive Science Society* (pp. 223–227). La Jolla, CA: Lawrence Erlbaum Associates, Inc.

Monsell, S. (1985). Repetition and the lexicon. In A. Ellis (Ed.), *Progress in the psychology of language* (pp. 147–195). London: Lawrence Erlbaum Associates, Inc.

Niswander-Klement, E., & Pollatsek, A. (2006). The effects of root frequency, word frequency, and length on the processing of prefixed English words during reading. *Memory and Cognition*, *34*, 685–702.

Pastizzo, M. J., & Feldman, L. B. (2004). Morphological processing: A comparison between free and bound stem facilitation. *Brain and Language*, *90*, 31–39.

Perea, M., Acha, J., & Fraga, I. (2008a). Lexical competition is enhanced in the left hemisphere: Evidence from different types of orthographic neighbors. *Brain and Language*, *105*, 199–210.

Perea, M., Duñabeitia, J. A., & Carreiras, M. (2008b). Masked associative/semantic priming effects across languages with highly proficient bilinguals. *Journal of Memory and Language*, *58*, 916–930.

Perea, M., Urkia, M., Davis, C. J., Agirre, A., Laseka, E., & Carreiras, M. (2006). E-Hitz: A word-frequency list and a program for deriving psycholinguistic statistics in an agglutinative language (Basque). *Behavior Research Methods*, *38*, 610–615.

Pollatsek, A., & Hyönä, J. (2005). The role of semantic transparency in the processing of Finnish compound words. *Language and Cognitive Processes*, *20*, 261–290.

Pollatsek, A., Hyona, J., & Bertram, R. (2000). The role of morphological constituents in reading Finnish compound words. *Journal of Experimental Psychology: Human Perception and Performance*, *26*, 820–833.

Pollatsek, A., Perea, M., & Carreiras, M. (2005). Does conal prime CANAL more than cinal? Masked phonological priming effects in Spanish with the lexical decision task. *Memory and Cognition*, *33*, 557–565.

Rastle, K., & Davis, M. H. (2003). Reading morphologically complex words: Some thoughts from masked priming. In S. Kinoshita & S. J. Lupker (Eds.), *Masked priming: State of the art* (pp. 279–305). Hove, UK: Psychology Press.

Rastle, K., Davis, M. H., Tyler, L. K., & Marslen-Wilson, W. D. (2000). Morphological and semantic effects in visual word recognition: A time-course study. *Language and Cognitive Processes*, *15*, 507–537.

Rastle, K. G., Davis, M. H., & New, B. (2004). The broth in my brother's brothel: Morpho-orthographic segmentation in visual word recognition. *Psychonomic Bulletin and Review*, *11*, 1090–1098.

Ratcliff, R., Gomez, P., & McKoon, G. (2004). A diffusion model account of the lexical decision task. *Psychological Review*, *111*, 159–182.

Reid, A., & Marslen-Wilson, W. D. (2000). Organising principles in lexical representation: Evidence from Polish. In L. R. Gleitman & A. K. Joshi (Eds.), *Proceedings of the twenty-second annual conference of the Cognitive Science Society* (pp. 405–410). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Sandra, D. (1990). On the representation and processing of compound words: Automatic access to constituent morphemes does not occur. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology*, *542A*, 529–567.

Shillcock, R., Ellison, M. T., & Monaghan, P. (2000). Eye-fixation behaviour, lexical storage and visual word recognition in a split processing model. *Psychological Review*, *107*, 824–851.

Shoolman, N., & Andrews, S. (2003). Racehorses, reindeers and sparrows: Using masked priming to investigate morphological influences on word identification. In S. Kinoshita & S. Lupker (Eds.), *Masked priming: The state of the art* (pp. 241–278). Hove, UK: Psychology Press.

Zwitserlood, P. (1994). The role of semantic transparency in the processing and representation of Dutch compounds. *Language and Cognitive Processes*, *9*, 341–368.

APPENDIX

Word and nonword primes and targets used in the experiments

Each triplet consists of (1) the related prime, (2) the unrelated prime, and (3) the target.

Experiment 1

bainugela-pentagono-egongela; *gaztetxe-nitratoa-bainuetxe*; *babestoki-salataria-dantzatoki*; *ahalera-augurio-altuera*; *geltoki-gorbata-jantoki*; *aldagela-oilaskoa-ikasgela*; *amaiera-arrunta-hizkera*; *hiriburu-laboreak-iparburu*; *egonezin-parasito-ikustezin*; *agintera-mundutar-aldaera*; *jokaera-janaria-sarrera*; *eguerdi-osatuta-galtzerdi*; *azterlan-estatutu-margolan*; *eserleku-elkargoa-gordeleku*; *jokabide-kanpotik-lanbide*; *aparkaleku-artistikoa-bizileku*; *amaorde-pretore-izenorde*; *orrialde-arduratu-sukalde*; *gizabide-tartetxo-ibilbide*; *aterpetxe-turistiko-argitaletxe*; *jangela-neutral-logela*; *argibide-nabaritu-autobide*; *eskualde-zientzia-etxalde*; *sumendi-kliniko-hondamendi*; *basajaun-bukatzea-etxejaun*; *helmuga-gozamen-urtemuga*; *buruhandi-bideoduna-burujabe*; *bidelagun-klorofila-bidesari*; *erdibide-sonbreru-erdipurdi*; *lanegun-diploma-langabe*; *semebitxi-kutsaketa-semeorde*; *dirusari-despiste-diruzain*; *alderdi-benetan-aldebakar*; *mendikate-liburutxo-mendilerro*; *mugae-*

zin-morroitu-mugagabe; *arrainjale-suspertuta-arrainkume*; *eskudiru-txalotua-eskualde*; *eskubakar-fundizioa-eskuarte*; *ezinegon-eskumara-ezinetorri*; *etxejabe-aktibatu-etxetxori*; *erdialde-amoniako-erdigune*; *hitzaurre-objetiboa-hitzaldi*; *eraberri-otomanoa-erabide*; *langela-budismo-lankide*; *eskubaloi-mozorroen-eskubide*; *burusoil-menditsu-buruargi*; *bidebanatze-bertsoetako-bidegurutze*; *lanordu-probeta-lanpostu*; *burubero-prosodia-burugogor*; *loreontzi-tximistan-lorezain*; *etxebizitza-erabakitzen-etxetresna*; *pasahitz-suizidio-pasabide*; *beinojale-pandejunu-ajunjale*; *jezdadxa-nidredue-beinoadxa*; *bebasdufi-selederie-tendzedufi*; *ehelare-eojoriu-eldoare*; *jaldufi-jurbede-gendufi*; *eltejale-uilesfue-ifesjale*; *emeiare-erronde-hizfare*; *hiriboro-leburaef-iperboro*; *ajunazin-peresidu-ifosdazin*; *ejindare-montoder-elteare*; *gufeare-generie-serrare*; *ajoarti-usedode-jeldzarti*; *ezdarlen-asdedodo-merjulen*; *asarlafo-alferjue-jurtalafo*; *gufebita-fenpudif-lenbita*; *eperfelafo-erdisdifue-bizilafo*; *emeurta-pradura-izanurta*; *urrielta-ertoredo-sofelta*; *jizebita-derdadxu-ibilbita*; *edarpadxa-dorisdifu-erjideladxa*; *genjale-naodrel-lujale*; *erjibita-neberido-eodubita*; *asfoelta-ziandzie-adxelta*; *somanti-flinifu-huntemanti*; *besegeon-bofedzae-adxageon*; *halmoje-juzeman-ordamoje*; *borohenti-bitautone-borogeba*; *bitalejon-flurukile-bitaseri*; *artibita-sunbraro-artiporti*; *lenajon-tiplume-lenjeba*; *samabidxi-fodsefade-samaurta*; *tiroseri-taspisda-tirozein*; *eltarti-banaden-eltabefer*; *mantifeda-liborodxu-mantilarru*; *mojeazin-murruido-mojejeba*; *erreingela-sospardode-erreinfoma*; *asfotiro-dxeludoe-asfoelta*; *asfobefer-kontiziue-asfoerda*; *azinajun-asfomere-azinadurri*; *adxageba-efdibedo-adxadxuri*; *artielta-emuniefu-artijona*; *hidzeorra-ubgadibue-hidzelti*; *arebarri-udumenue-arebita*; *lenjale-botismu-lenfita*; *asfobelui-muzurruan-asfobita*; *borosuil-mantidso-boroerji*; *bitabenedza-bardsuadefu-bitajorodza*; *lenurto-prubade-lenpusdo*; *borobaru-prusutie-borojujur*; *luraundzi-dximisden-lurazein*; *adxabizidze-arebefidzan-adxadrasne*; *pesehidz-soizitiu-pesebita*.

Experiment 2

bidegurutze-borrokalari-etorbide; *mugazain-lokutore-helmuga*; *loretoki-morroilo-ekilore*; *berriemaile-eskarmentua-ezkonberri*; *langabezia-konstantea-eskulan*; *alderdi-sistema-lurralde*; *etxebizitza-errealitate-ikastetxe*; *lekualdaketa-lasaitasunez-udaleku*; *mendikate-anarkista-sumendi*; *ezinegon-automata-jasanezin*; *erabide-orbital-bestera*; *neurrigabe-bigarrengo-salneurri*; *dirusari-multxoka-eskudiru*; *erdigune-paritate-gauerdi*; *eginahal-atributo-lanegin*; *hitzaurre-antologia-pasahitz*; *pasahitz-leopardo-mahaspasa*; *lagunarte-segurtatu-neskalagun*; *gelakide-muskerra-aldagela*; *gizongai-turutari-legegizon*; *arrainjale-koskatzean-amuarrain*; *semeorde-mudantza-gizaseme*; *burugogor-aportazio-asteburu*; *jaunartze-berotasun-basajaun*; *asteburu-panorama-burugogor*; *eskulan-otsaila-langabezia*; *amuarrain-tabernari-arrainjale*; *legegizon-penagarri-gizongai*; *jasanezin-zanpatuta-ezinegon*; *neskalagun-*

ezberdinaz-lagunarte; *mahaspasa-zabalketa-pasahitz*; *udaleku-samindu-lekualdaketa*; *ezkonberri-euskaratua-berriemaile*; *salneurri-semaforoa-neurrigabe*; *lanegin-terapia-eginahal*; *etorbide-txerriki-bidegurutze*; *pasahitz-estimulo-hitzaurre*; *aldagela-zorigabe-gelakide*; *ekilore-zozoilo-loretoki*; *sumendi-sonatua-mendikate*; *bestera-jainkoa-erabide*; *gauerdi-pintzel-erdigune*; *eskudiru-eskalatu-dirusari*; *gizaseme-konplexu-semeorde*; *helmuga-kaletar-mugazain*; *basajaun-ordutegi-jaunartze*; *lurralde-laguntza-alderdi*; *ikastetxe-bederatzi-etxebizitza*; *fitagorodza-furruseleri-adurfita*; *togezeik-lusodura-haltoge*; *luradusi-turruilu-asilura*; *farriateila-ansertakdoe-azsukfarri*; *lekgefazie-sukndekdae-ansolek*; *eltarti-nindate-lorrelta*; *adxafizidze-arraelideda-isendadxa*; *lasoeltesade-leneidenokaz-otelaso*; *taktiseda-ekersinde-notakti*; *azikaguk-eodutede-jenekazik*; *arefita-urfidel-fandare*; *kaorrigefa-figerrakgunelkaorri*; *tironeri-toldxuse-ansotiro*; *artigoka-perideda-geoarti*; *agikehel-edrifodu-lekagik*; *hidzeorra-ekdulugie-penehidz*; *penehidz-laupertu-tehenpene*; *legokerda-nagordedo-kanselegok*; *galesita-tonsarre-eltegale*; *gizukgei-doroderi-lagagizuk*; *erreikjela-sunsedzaek-etoerreik*; *nataurta-totekdze-gizenata*; *forogugur-epurdeziu-endaforo*; *jeokerdza-farudenok-fenejeok*; *endaforo-pekurete-forogugur*; *ansolek-udneile-lekgefazie*; *etoerreik-defarkeri-erreikjela*; *lagagizuk-pakegerri-gizukgei*; *jenekazik-zekpedode-azikaguk*; *kanselegok-azfartikez-legokerda*; *tehenpene-zefelsade-penehidz*; *otelaso-netikto-lasoeltesade*; *azsukfarri-aonseredoe-farriateila*; *nelkaorri-nateburue-kaorrigefa*; *lekagik-darepie-agikehel*; *adurfita-dxarrisi-fitagorodza*; *penehidz-anditolu-hidzeorra*; *eltegale-zurigefa-galesita*; *asilura-zuzuilu-luradusi*; *notakti-nukedoe-taktiseda*; *fandare-jeiksue-arefita*; *geoarti-pikdzal-artigoka*; *ansotiro-anseledo-tironeri*; *gizenata-sukplaxo-nataurta*; *haltoge-selader-togezeik*; *fenejeok-urtodagi-jeokerdza*; *lorrelta-legokdze-eltarti*; *isendadxa-fataredzi-adxafizidze.*

Experiment 3

bildur-nekazari-bilakatu; *fisiko-txango-fiskal*; *problema-zalantza-produktu*; *heriotz-pekatari-herrikoi*; *belarri-kongresu-beldurtu*; *alargun-orrialde-alabaina*; *alkate-profeta-alkohol*; *bezero-printze-bezpera*; *sinbolo-izkutuan-sinadura*; *aingeru-presaka-aintzin*; *aberats-sailkatu-abeslari*; *formazio-gustora-formula*; *nahaste-udaberri-nahigabe*; *garraio-sakratu-garratz*; *harreman-kapitain-harkaitz*; *defentsa-aparteko-definitu*; *esparru-jokabide-espiritu*; *bazkari-ahalmena-baztertu*; *kontsumo-teologia-kontratu*; *arbaso-tomate-arbela*; *sorbalda-prentsa-sorrera*; *erlazio-zabalik-erlijio*; *bizkor-itzulpen-biztanle*; *bildots-hautagai-bilaketa*; *finantza-polizia-finkatu*; *erakusle-ibiltari-eragotzi*; *tximista-beretzat-txikiena*; *bultzatu-teatro-bulego*; *artikulu-itsasoa-artzain*; *abenduan-momentua-abentura*; *agentzi-ezabatu-agerpen*; *arrantza-merkatu-arrisku*; *kondaira-itzalean-kondizio*; *tximista-orokorki-karlista*; *belarri-zehaztu-eztarri*; *natural-termino-ostiral*; *plastiko-niregana-organiko*; *bortitz-tes-*

tigu-zuhaitz; *pantaila-pozgarri-borobila*; *molekula-ministro-pelikula*; *sintesi-pintore-analisi*; *diseinu-oxigeno-erreinu*; *estetika-omenaldi-fonetika*; *jatorri-zeregin-oinarri*; *parrokia-salbamen-argazkia*; *aintzira-kondizio-kondaira*; *txarrena-menditik-txostena*; *akordio-zientzi-erradio*; *nafarroa-jakiteko-zigarroa*; *misterio-pribatua-inpresio*; *gasolina-suposatu-doktrina*; *funtzio-posible-posizio*; *heriotz-trafiko-zorrotz*; *txartela-murgildu-ikasgela*; *autonomo-kartzela-kontsumo*; *harkaitz-primeran-eskutitz*; *hamahiru-petrolio-altzairu*; *justizia-normalki-agentzia*; *bautista-lorategi-protesta*; *kapitulu-lehiotik-artikulu*; *eragile-zintzoa-langile*; *fantasia-organiko-burgesia*; *kritiko-sudurra-publiko*; *adibide-borroka-helbide*; *akademia-leporatu-ekonomia*; *atseden-zurezko-laurden*; *moltur-namezero-molemedu*; *fosomi-dxengi-fosmel*; *primlake-zelendze-pritumdu*; *haroidz-pamedero-hallomio*; *malello-mingrasu-malturdu*; *elergun-illoelta-elemeone*; *elmeda-prifade-elmihil*; *mazari-prondza-mazpare*; *sonmili-ozmuduen-soneture*; *eongaru-praseme-eondzon*; *emareds-seolmedu-emaslero*; *firkezoi-gusdire-firkule*; *nehesda-utemallo-nehogema*; *gelleoi-semredu-gelledz*; *hellaken-mepodeon-hermeodz*; *tafandse-eperdami-tafonodu*; *aspellu-jimemota-asporodu*; *mezmero-ehelkane-mezdardu*; *mindsuki-dailigoe-mindredu*; *ermesi-dikeda-ermale*; *sirmelte-prandse-sillare*; *arlezoi-zemelom-arlojoi*; *mozmir-odzulpan-mozdenla*; *moltids-heudegeo-molemade*; *fonendze-pilozoe-fonmedu*; *aremusla-omoldero-aregidzo*; *dxokosde-maradzed-dxomoane*; *muldzedu-daedri-mulagi*; *erdomulu-odsesie-erdzeon*; *emantuen-kikandue-emandure*; *egandzo-azemedu-egarpan*; *ellendze-karmedu-ellosmu*; *minteore-odzelaen-mintozoi*; *dxokosde-irimirmo-merlosde*; *malello-zahezdu-azdello*; *nedurel-darkoni-isdorel*; *plesdomi-noragene-irgenomi*; *mirdodz-dasdogu-zuheodz*; *pendeole-pizgello-mirimole*; *kilamule-konosdri-palomule*; *sondaso-pondira-eneloso*; *tosaonu-ixogani-allaonu*; *asdadome-ikanelto-finadome*; *jedillo-zaragon-ionello*; *pellimoe-selmekan-ergezmoe*; *eondzore-mintozoi-minteore*; *dxellane-kantodom-dxisdane*; *emirtoi-zoandzo-alletoi*; *nefellie-jemodami-zogellie*; *kosdaroi-promedue-onprasoi*; *gesilone-supisedu-timdrone*; *fundzoi-pisomla-pisozoi*; *haroidz-drefomi-zillidz*; *dxerdale-kurgoltu-omesgale*; *eudiniki-merdzale-mindsuki*; *hermeodz-prokaren-asmudodz*; *hekehoru-padriloi-eldzeoru*; *jusdozoe-nirkelmo-egandzoe*; *meudosde-liredago-pridasde*; *mepodulu-lahoidom-erdomulu*; *aregola-zondzie-lengola*; *fendesoe-irgenomi-murgasoe*; *mrodomi-sutulle-pumlomi*; *etomota-millime-halmota*; *emetakoe-lapiredu-aminikoe*; *edsatan-zurazmi-leurtan*.