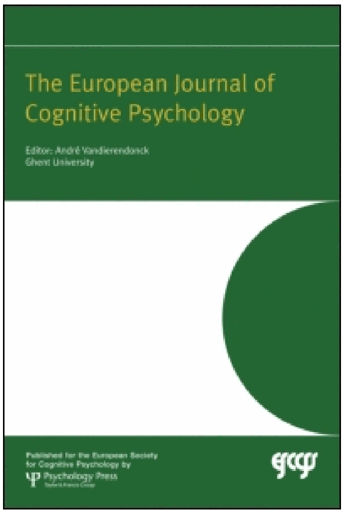

European Journal of Cognitive Psychology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713734596

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Jon Andoni Duñabeitia [a]; Alejandro Marín [a]; Alberto Avilés [a]; Manuel Perea [b]; Manuel Carreiras [a]
[a] Universidad de La Laguna, Tenerife, Spain [b] Universitat de València, València, Spain

First Published on: 19 August 2008

To link to this Article: DOI: 10.1080/09541440802281142
URL: http://dx.doi.org/10.1080/09541440802281142

EUROPEAN JOURNAL OF COGNITIVE PSYCHOLOGY
0000, 00 (00), 1–20

Psychology Press
Taylor & Francis Group

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Jon Andoni Duñabeitia, Alejandro Marín, and Alberto Avilés
Universidad de La Laguna, Tenerife, Spain

Manuel Perea
Universitat de València, València, Spain

Manuel Carreiras
Universidad de La Laguna, Tenerife, Spain

How elderly adults process morphologically complex words is still a matter of controversy. The present study explored whether compound word recognition is affected by ageing. A group of young adults and a group of older healthy adults were tested on a lexical decision task. Compound words were presented primed by their first constituent (*book-BOOKSHOP*), their second constituent (*shop-BOOKSHOP*), or by an unrelated word (*house-BOOKSHOP*). Results revealed that morphological processing is fully preserved in advanced age and that the magnitude of the constituent priming effect was similar for young and older adults.

Keywords: Compound words; Morphological priming; Ageing.

How readers understand the meaning of morphologically complex words is a fundamental question for models of visual-word recognition (see Diependaele, Sandra, & Grainger, 2005). Words vary largely in terms of their morphological structure, ranging from monomorphemic words (i.e., words composed of a single meaningful unit, like *walk*) to polymorphemic words (i.e., words composed of more than a single morpheme, like *walker*).

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 article has been partially supported by Grants SEJ2004-07680-C02-02/PSIC, SEJ2006-09238/PSIC, and SEJ2005-05205/EDU from the Spanish Government, and by Grant BFI05.310 from the Basque Government. The authors thank Lars-Göran Nilsson and three anonymous reviewers for their helpful comments on an earlier draft. Thanks are also due to Margaret Gillon-Dowens for her support and priceless patience.

http://www.psypress.com/ecp DOI: 10.1080/09541440802281142

Empirical evidence from healthy young adults suggests that these polymorphemic words are decomposed early in the visual word recognition process (see Frost, Grainger, & Rastle, 2005a, for review). However, there is less evidence regarding other populations, such as children and older adults. In the present study we explore how older adults recognise morphologically complex words, and more specifically, how they recognise compound words.

COMPOUND WORDS AND CONSTITUENT PRIMING EFFECTS

Compound words are created from the union of two or more lexemes (e.g., *foot + ball = football*). These compound word forms are not necessarily written as a single unit (closed or "solid" compounds, as in *football*), but can also be scripted in a hyphenated fashion (e.g., *editor-in-chief*) or even in an unlinked way (e.g., *science fiction*). Furthermore, compound words can vary largely in degree of transparency, that is, in how the meaning of the compound word is tied to the meaning of each of the constituents. Hence, one can easily come across compound words in which the meaning of both constituents is directly related to the whole-word meaning (e.g., a transparent compound, such as *bedroom*), compound words in which only the meaning of the first or second lexeme fits the general meaning of the word (e.g., semiopaque compounds such as *jailbird* or *strawberry*), and compound words in which none of the constituent meanings coincide with the whole-word meaning (e.g., opaque compounds such as *deadline*; see Libben, 1998; see also Libben, Gibson, Yoon, & Sandra, 2003). In the present study, we focus on how transparent, solid compounds are processed and decomposed when presented visually—bear in mind that these compounds are critical to test morpho-orthographic versus morphosemantic decomposition effects (see Diependaele et al., 2005).

There is a large body of evidence consistently showing that young adult readers decompose compound words into their constituents at early stages of lexical access (e.g., Duñabeitia, Perea, & Carreiras, 2007b; Fiorentino & Poeppel, 2007; Hyönä & Pollatsek, 1998; Juhasz, Starr, Inhoff, & Placke, 2003; Koester, Gunter, & Wagner, 2007; Pollatsek, Hyönä, & Bertram, 2000). The most robust evidence on morphological processing has been obtained in priming experiments. For instance, a number of studies have shown a robust priming effect of the whole compound when primed by one of the constituent lexemes. Furthermore, it seems that the magnitude of the priming effect produced by the first constituent (e.g., *milk*-*MILKMAN*) and by the second constituent (e.g., *man*-*MILKMAN*) is approximately the same (Jarema, Busson, Nikolova, Tsapkini, & Libben, 1999; Libben et al., 2003; Monsell, 1985; Sandra, 1990; Zwitserlood, 1994). For instance, Zwitserlood (1994) used immediate partial repetition priming, presenting the compound word for 300 ms followed by one of its constituents (e.g., *milkman-MILK* and *milkman-MAN*). She found similar priming effects for the first and second constituents. Importantly, these constituent priming effects have also been replicated using very brief prime exposures and briefly presented primes (i.e., the masked priming paradigm; Forster & Davis, 1984). Shoolman and Andrews (2003) presented the participants with compound target words (e.g., *BOOKSHOP*) that could be preceded by the brief presentation (57 ms) of either the first constituent (e.g., *book*), the second constituent (e.g., *shop*), or an unrelated word. For transparent compound words, they observed similar priming for the first and for the second constituents relative to the unrelated priming condition. Very recently, and with a more extreme manipulation, Duñabeitia, Laka, Perea, and Carreiras (in press-b) replicated these findings using a masked priming paradigm. Duñabeitia and colleagues presented compound target words which were briefly preceded by different compound words that shared either the first constituent (e.g., *milkshake-MILKMAN*), the second constituent (e.g., *postman-MILKMAN*), or by noncompound words that did not share any of the lexemes. Their results confirmed those from previous studies revealing a similar constituent priming effect that does not depend on the position of the shared lexeme (Monsell, 1985; Sandra, 1990; Shoolman & Andrews, 2003; Zwitserlood, 1994). In sum, constituent priming is a well-established phenomenon that can be interpreted in terms of a parallel activation of separate representations of the morphemic constituents (in line with Rastle, Davis, & New, 2004; Rastle, Davis, Tyler, & Marslen-Wilson, 2000; see also Duñabeitia, Perea, & Carreiras, 2007a, in press-c).

VISUAL WORD RECOGNITION IN YOUNG AND ELDERLY READERS: EVIDENCE FROM PRIMING

In priming experiments, the effect of a related prime on target performance is compared to the effect of an unrelated prime on the same target. That is, participants do not make explicit judgement on the link between the prime and the target, and hence this processing facilitation (i.e., a "priming" effect) is usually thought to reflect an automatic access to activation –at least when the stimulus-onset asynchrony between the prime and the target is brief. There are different types of possible relationships between prime and target words, based either on a pure orthographic/form overlap (e.g., *house-HORSE*; see Carreiras, Perea, & Grainger, 1997; Spieler & Balota, 2000), on a similarity at morpheme level (e.g., *reaction-REFORM*; see Giraudo & Grainger, 2003; Marslen-Wilson, Ford, Older & Zhou, 1996), or on semantic relationship between concepts (e.g., *nurse-DOCTOR*; see Duñabeitia, Carreiras, & Perea, in press-a; Meyer & Schvaneveldt, 1971; Perea, Duñabeitia, & Carreiras, 2008; Perea & Gotor, 1997; Perea & Rosa, 2002). Although the priming paradigm has been largely used in young adult samples, elderly readers have not been so extensively tested under priming conditions. Some of the priming studies that have tested elderly participants on semantic relationships between concepts have shown an interesting priming pattern, revealing that senior readers exhibit a greater semantic priming effect than younger readers (the so-called *hyperpriming*; Laver, 2000; Laver & Burke 1993; see Giffard, Desgranges, Piolino, Eustache, & Kerrouche, 2003, for a review). As indicated by Giffard and colleagues, this hyperpriming effect may be reflecting a storage deficit for specific details of the concepts (i.e., semantic priming could be an instance of repetition priming in those individuals), a mere artefact of a general slowing hypothesis (i.e., larger priming effects for the slower individuals), or some differing attentional processing (i.e., different strategies of processing for the elderly individuals). However, the presence of hyperpriming in semantic priming experiments is not entirely consistent, and a number of studies have reported that the magnitude of the semantic priming effects does not interact with age (Balota, Black, & Cheney, 1992; Balota & Duchek, 1988; Howard, McAndrews, & Lasaga, 1981; Ober, Shenaut, Jagust, & Stillman, 1991). With respect to sublexical manipulations, Carreiras, Baquero, and Rodríguez (in press) recently conducted a syllable priming experiment (e.g., does *ca*****-*CASINO* differ from *cas****-*CASINO*?; see Carreiras & Perea, 2002) with senior readers. Carreiras and colleagues found that not only subword unit processing is preserved with age (i.e., there was a significant syllable priming effect for the elderly), but the magnitude of the priming effect was greater for senior readers than for young adults. In fact, the syllable congruency effect was approximately 10 times larger for older readers than for younger readers who were tested in a previous experiment with the same materials (Carreiras & Perea, 2002), revealing that the size of the orthographic/phonological priming effect is enlarged as a function of ageing. Hence, these results from sublexical priming together with those from previous semantic priming studies showing greater magnitudes of the effects for the elderly participants support the existence of a hyperpriming effect that emerges as a function of age.

The very few studies that have tackled morphological priming in the elderly have reached the conclusion that morpheme processing is preserved in advanced age. Kavé and Levy (2004) tested Hebrew participants with Alzheimer's disease and aged control participants in a cross-modal priming experiment. They found that healthy older readers produced strong morphological priming in the absence of phonological priming (similarly to Bentin & Feldman, 1990; see also Frost, Deutsch, Gilboa, Tannenbaum,

& Marslen-Wilson, 2000). These results led them to conclude that the morphological relationships that exist among lexical items are preserved (see also Stamatakis & Tyler, 2006, for an fMRI study). However, several points should be highlighted regarding these findings. First, Kavé and Levy did not include a group of young adults in their experiment—note that their interest was to compare healthy aged participants with patients with Alzheimer's disease, and hence nothing could be said about dissimilarities in morphological priming effects due to age differences. This comparison is highly interesting in order to explore the existence of a *morphological hyperpriming* effect. Second, their experiments were conducted in Hebrew, and the morphological properties of Semitic languages are very different to those of Indo-European languages (see Frost, Kugler, Deutsch, & Forster, 2005b). For instance, words in Hebrew are composed of a consonantal root that represents an independent morphological unit, embedded within other letters (e.g., *RGL* in *meRaGeL*, the Hebrew for *a spy*), and in many cases, shared roots imply shared meaning (e.g., *RGL* in *RiGuL*, translated as *spying*). Thus, considering that root extraction is a necessary process for Hebrew readers but not for non-Semitic language users, it is not a simple task to generalise their results to other languages.

THE PRESENT STUDY: GOALS AND PREDICTIONS

The present study is aimed at exploring morphological decomposition of transparent compound words in aged readers. A group of healthy elderly adults was tested in a constituent priming experiment: Compound words served as targets (e.g., *BOOKSHOP*) and could be briefly preceded by their first constituent lexeme (e.g., *book*), their second constituent lexeme (e.g., *shop*), or by an unrelated word (e.g., *house*). To test whether or not the elderly readers showed a morphological hyperpriming effect, a group of younger readers was also tested with the same materials. Considering previous research, several main predictions can be made. Prior research has shown that reading latencies (reaction times) tend to increase with age (Allen, Madden, & Crozier, 1991; Allen, Sliwinski, & Bowie, 2002; Lima, Hale, & Myerson, 1991; Ratcliff, Thapar, Gómez, & McKoon, 2004b). However, although reading times are generally longer for older adults, language processing is thought to be minimally affected by ageing (Davidson, Zacks, & Ferreira, 2003; Waters & Caplan, 2005)—that is, the longer reaction times may just be a consequence of a general slowing (the general slowing hypothesis; see Birren, 1965; Cerella, 1985, 1990; Lima et al., 1991; Myerson, Hale, Chen, & Lawrence, 1997). Hence, according to this hypothesis, a first straightforward prediction is that elderly readers should produce longer reaction times than younger adults. Second, according to recent findings in subword unit processing (at a syllable level), robust priming effects can be expected for the morphologically related primes with respect to the unrelated condition (Carreiras et al., in press). Indeed, if the results obtained in Hebrew (Kavé & Levy, 2004) can be generalised to Indo-European languages, and if morphological relationships are indeed preserved in aged readers, a robust constituent priming effect should be observed for the elderly participants. But importantly, there is a key aspect of this study that could shed some light on the way in which connections at the orthographic, morphological, and semantic levels are affected by age. The compound words employed in the experiment were always transparent; that is, the meaning of the whole-words were directly derived from its constituents (i.e., there was a shared orthographic and semantic component between primes and targets). Thus, this manipulation allows us to test whether, similarly to previous findings with semantic priming, the observed effects are of greater magnitude for elderly than for younger readers (a hyperpriming effect; Laver, 2000; Laver & Burke, 1993) or, alternatively, whether they are of the same magnitude for both groups (as reported, among others, by Balota et al., 1992, and Balota & Duchek, 1988). To our knowledge, this critical test with transparent compounds has not been conducted in previous research.

METHOD

Participants

A total of 48 Spanish speakers took part in the data collection. Twenty-four of them were undergraduate students from the University of La Laguna (the young adult readers group). They all had normal or corrected-to-normal vision. Another group of 24 elderly participants was also selected for the current experiment (the elderly readers group; mean age 65.6 ± 7.5, range: 60–81). They were all healthy, active, community-dwelling individuals, and none of them reported having suffered medical or neurological diseases causing cognitive impairment or psychiatric disorder. All of the seniors had corrected vision for reading, and they wore their glasses in the experiment. These participants had attended regular scholar education for an average of 8.5 years (± 3.1).

Neuropsychological study

All the 24 elderly readers underwent a neuropsychological testing session that lasted for approximately 1 hour. This protocol included a Spanish and Latin-American standardised set of neuropsychological tests (Peña-Casanova, 2005), in which general cognitive status, functional-emotional status, memory, language, attention, and executive abilities were assessed. Special attention was paid to screening for dementia, and four standardised tests were applied for this: the Mini-Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975), the short version of the Geriatric Depression Scale (Yesavage, 1988), the Lawton Geriatric Functionality Scale (Lawton, 1971), and a self-perception memory loss test based on a questionnaire about memory complaint (Cano, Ruiz, & Plata, 2002). The 24 participants obtained scores similar to or above those expected in all the tests and questionnaires. Scores from these participants are presented in Table 1.

Materials

Before creating the final list of materials for this experiment, a total of 24 workers and undergraduate students from the University of La Laguna voluntarily completed a questionnaire that served as a norming survey of the

TABLE 1
Neuropsychological scores for participants in the elderly group

Test	*Average*	*Standard deviation*	*ES***
Education (years)	8.45	3.12	
MMSE*	27.6	1.90	24
QSM	7.91	6.04	19
Lawton	8	0	6
Yesavage	2.3	3.2	5
FVS	14.9	2.7	13
FVF	11.7	3.2	11
DEN	57	4.1	50
RAVLT (learning)	39.9	6.5	39
RAVLT (short term)	9	2.1	6
LISTA B	7	2.35	4
RAVLT (long term)	9	1.9	8
REC	12.7	4.2	10
CFCR	32	18.1	29
TMT (time)	50.4	11.9	60
TMT	23.86	1.12	20
D-S	34.4	1.5	27
Refrains	8.6	2.7	7
Resemblances	16.3	0	13
Grafo-Motor Series	3	0	3

*MMSE: Mini-Mental State Examination. QSM: Subjective Memory Complain. FVS: Semantic Verbal Fluency. FVF: Phonologic Verbal Fluency. DEN: Naming. RAVLT: Rey Auditory Verbal Learning Test. REC: Recall. CFCR: Rey Figure (Copy). TMT: Trail Making Test. D-S: Digit-Symbol. **ES: Expected Scores (fit by age and scholar education in each participant and to all groups).

transparency of the compound words. None of these participants took part in the data collection for the experiment. These participants were presented with a selected list of 82 Spanish compound words that were previously chosen from the Spanish lexical database (LEXESP; Sebastián-Gallés, Martí, Carreiras & Cuetos, 2000). These words were at first selected by two independent external judges who classified them as transparent compound words. In order to directly asses the transparency degree of these words, the 24 participants had to rate them following a 1–7 scale, 1 being completely opaque and 7 completely transparent. They were told to consider a compound word as transparent whenever the two constituents were directly related to the whole-word meaning (e.g., *blackboard*), and to rate the compound word as opaque when the meaning of the two constituents was not related to the general meaning of the word (e.g., *deadline*). They were instructed to give a medium rating when the meaning of only one of the two constituent lexemes was linked to the whole-word meaning (e.g., *strawberry*, *jailbird*). The results showed that 13 of the 82 compound words were rated with a mean score less than 4 (mean: 3.2 ± 0.7), indicating that the degree of transparency was low. Therefore, these 13 words were discarded for the experiments. The other 69 compound words were rated with a mean score of 5.7 (± 0.9), indicating that the meaning of both constituent lexemes was highly related to the general meaning of the whole compound word.

The 69 compound words rated as transparent in the norming study were used as target words for the present experiment. These words were analysed with the B-Pal software that provides the most relevant indexes influencing visual word recognition (Davis & Perea, 2005). These compound words were low frequency words (mean frequency: 3.23 ± 7.75 appearances per million words), and had a mean length of 9.9 ± 1.4 characters. They had a mean number of 0.3 ± 0.5 orthographic neighbours according to the index *N* (Coltheart, Davelaar, Jonasson, & Besner, 1977). The first constituent lexemes of these compound words had a mean frequency of 162.39 ± 331.91, a mean length of 4.7 ± 0.8 letters, and a mean number of 11.5 ± 7.7 orthographic neighbours. The second constituent lexemes closely matched these statistics, with a mean frequency of 145.88 ± 240.44, a mean length of 5.2 ± 1.2 characters, and a mean number of 9.1 ± 7.2 orthographic neighbours. An extra set of 69 different words was selected as unrelated prime words for the compound words. These words were matched as closely as possible to the constituent lexemes in frequency (157.29 ± 177.89), number of letters (5.3 ± 1.1), and number of orthographic neighbours (6.6 ± 6.0). The 69 compound words were used as targets (e.g., *PASATIEMPO*, meaning *pastime*, composed of *pasa*[*pass*] + *tiempo*[*time*]), and could be preceded by (1) the first constituent lexeme (e.g., *pasa-PASATIEMPO*), (2) the second constituent lexeme (e.g., *tiempo*-*PASATIEMPO*), or (3) a completely unrelated word (e.g., *mujer*-*PASATIEMPO*; *mujer* is the Spanish for *woman*). Another set of 207 Spanish noncompound words of approximately the same length and frequency as the target compounds was also selected as target words, so that the relatedness proportion of compound words in the experiment was kept constant at 25%. These noncompound words were preceded by a set of prime words composed by 207 different words. An extra set of 276 nonwords was created in order to make the lexical decision possible. These nonwords were created by replacing three or four letters from the target words (e.g., *PUFAMIESPO* from *PASATIEMPO*), and were preceded by nonword primes created by replacing two or three letters from the prime words (e.g., *pufa*, *miespo*, *rufer*). Three different lists were created with the stimuli, so that each critical target appeared only once in each list, but each time in a different priming condition. Different participants were assigned to each of the lists.

Procedure

The young readers group was tested in a well-lit, soundproofed room of the Cognitive Neuroscience and Psycholinguistics Group's installations at the University of La Laguna, while the elderly readers group was tested individually in a well-lit, quiet room at the senior centres where they were recruited. 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 fixation point (+) for 500 ms, followed by the displaying of the lowercase prime for 250 ms, and immediately followed by the presentation of the uppercase target. Primes and targets were presented in 12 point Courier New font. For the young readers group, target items remained on the screen for 2500 ms or until a response was given. For the elderly readers group, target items remained for 3500 ms or until a response was given. This was in order to provide aged participants with enough time for their responses, bearing in mind that older participants' response times tend to be much higher than those of younger participants. All participants were instructed to press the "M" button on the keyboard when the item displayed was a real Spanish word, and the "Z" button when it was not. They were told to do so as fast and as accurately as possible. All participants completed practice trials before the experiment for warm-up purposes. All the items were randomly presented to avoid order repetition effects across participants.

TABLE 2
Mean lexical decision times (ms) and percentage of errors (in parentheses) for word targets in the experiment

	Priming condition			*Priming effect*	
	First lexeme	*Second lexeme*	*Unrelated word*	*First lexeme*	*Second lexeme*
Young group	759 (5.98%)	757 (4.71%)	842 (8.33%)	83 (2.35)	85 (3.62)
Elderly group	1550 (8.70%)	1541 (7.97%)	1662 (7.79%)	112 (–0.91)	120 (–0.18)

Mean reaction times for nonwords and percentage of errors were 858 and 2.05% for the young adult group and 1976 and 13.59% for the elderly group.

RESULTS

Response latencies beyond or above three standard deviations from the mean values of each experimental condition and reaction times associated to incorrect responses (4.2% of the data) were excluded from the response time analyses.[1] Mean response times and percentages of errors are presented in Table 2. Planned comparisons were conducted to assess the effect of constituent priming (i.e., the difference between the unrelated condition and each constituent). We report only *F* analyses over participants, since there is evidence showing that *F*1 is the appropriate analysis for testing the significance of the effects in counterbalanced designs (see Raaijmakers, 2003; Raaijmakers, Schrijnemakers, & Gremmen, 1999). Group (young readers, elderly readers) was included as a between-subject variable. List (List 1, List 2, List 3) was also included in the analyses as a dummy variable to extract the variance due to the counterbalanced lists (see Pollatsek & Well, 1995).

First constituent priming

The results from the reaction time analyses revealed a significant effect of the first constituent priming relative to the unrelated condition, $F(1, 42) = 40.09$, $p < .001$, $MSE = 56740$, $1–\beta = 1$: Participants recognised much faster (97 ms faster) compound words when preceded by their first constituent. The main effect of group was also significant (young readers being faster than elderly readers), $F(1, 42) = 58.80$, $p < .001$, $MSE = 264763$, $1–\beta = 1$. But the key

[1] Even though on a priori grounds one could argue that the three standard deviation cutoff might leave a high number of outlier values in the data (e.g., see Ratcliff, 1993), it should be noted that the data trimming procedure did not have any significant impact on the results. An analysis of the same data with a two standard deviation cutoff produced exactly the same results, with almost identical *p*-values for the observed effects.

finding here is that there were no signs of an interaction between these two factors, $F(1, 42) = 0.35$, $p > .91$, $MSE = 5674$, $1–\beta = .15$.

Analyses on the percentages of errors did not show any significant effects. There were no statistical differences between the error rates for compound words preceded by their first constituent or by unrelated words, $F(1, 42) = 0.41$, $p > .50$, $MSE = 31$, $1–\beta = .10$. The effect of group was not significant, $F(1, 42) = 0.55$, $p > .45$, $MSE = 52$, $1–\beta = .11$. The interaction between the two factors was not significant either, $F(1, 42) = 2.06$, $p > .15$, $MSE = 31$, $1–\beta = .29$.

Second constituent priming

Compound words preceded by their second constituent were recognised significantly faster (102 ms faster) than those preceded by an unrelated word, $F(1, 42) = 37.04$, $p < .001$, $MSE = 6802$, $1–\beta = 1$. The effect of group was also significant, showing that the group of elderly readers made longer response times than the group of young readers, $F(1, 42) = 61.71$, $p < .001$, $MSE = 250290$, $1–\beta = 1$. Importantly, the interaction between the two factors was not significant, $F(1, 42) = 1.12$, $p > .25$, $MSE = 6802$, $1–\beta = .18$.

The percentage of error analyses showed no reliable effects. Compound words preceded by their second constituent were read equally accurately than compound words preceded by an unrelated word, $F(1, 42) = 2.39$, $p > .13$, $MSE = 30$, $1–\beta = .33$. The effect of group was not significant, $F(1, 42) = 0.74$, $p > .35$, $MSE = 60$, $1–\beta = .13$. The interaction between the two factors only approached significance, $F(1, 42) = 2.91$, $p = .09$, $MSE = 30$, $1–\beta = .38$.

First constituent priming versus second constituent priming

The priming effects for compound words preceded by their first or their second constituent lexemes did not show any significant difference, $F(1, 42) = 0.11$, $p > .70$, $MSE = 5638$, $1–\beta = .06$. The effect of group was significant, $F(1, 42) = 56.93$, $p < .001$, $MSE = 261505$, $1–\beta = 1$, but the interaction between the two factors was not, $F(1, 42) = 0.04$, $p > .80$, $MSE = 5638$, $1–\beta = .05$.

The analyses on the error rates showed that compound words preceded by their first constituent were recognised with similar accuracy to compound words preceded by their second constituent, $F(1, 42) = 1.07$, $p > .30$, $MSE = 22$, $1–\beta = .17$. The effect of group was significant, revealing that the group of elderly readers made more errors than the group of young readers, $F(1, 42) = 4.57$, $p < .05$, $MSE = 47$, $1–\beta = .55$. The interaction between the two factors was not significant, $F(1, 42) = 0.08$, $p = .78$, $MSE = 22$, $1–\beta = .06$.

There is a caveat, however: Response times for older individuals were longer than response times for younger individuals, and hence one could argue that this may complicate a straightforward interpretation of the present findings. To minimise the proportional increase in the response times between groups, we performed the same analysis with a logarithmic transformation of the response times. The ANOVAs on the transformed data confirmed the results obtained with the nontransformed data. Compound words preceded by their first constituent were recognised significantly faster than in the unrelated condition, $F(1, 42) = 51.21$, $p < .001$, $MSE = 0.004$, $1–\beta = 1$. The priming effect for the second constituent was also significant, $F(1, 42) = 52.27$, $p < .001$, $MSE = 0.004$, $1–\beta = 1$. No differences were found between the priming effects for the first and second constituents, $F < 1$ and $p > .90$; and finally, none of the interactions with group resulted significant, all Fs < 1.4 and all ps $> .25$.

DISCUSSION

The present results can be summarised as follows: (1) Young adult readers show robust constituent priming effects, which are independent of the position of the lexeme (initial, final); (2) older adults also show sizeable constituent priming effects for both the first and second lexemes; and (3) the magnitude of the constituent priming effects is similar for the young and the older adults, despite the fact that reaction times were longer for older than for younger adults.

As stated in the introduction, constituent priming effects have been consistently found at different ranges of stimulus–onset asynchronies (ranging from 50 to 300 ms; see Isel, Gunter, & Friederici, 2003, for a review). Importantly, the benefit of previewing the first constituent (e.g., *book*-*BOOKSHOP*) and the second constituent (e.g., *shop*-*BOOKSHOP*) is similar. That is, the two lexemes seem to exert a similar influence on compound word recognition (e.g., Shoolman & Andrews, 2003). The present results converge with previous studies that have explored the same issue in young adult populations, obtaining constituent priming effects of the same magnitude for the first and second lexeme. Importantly, this is the first time that a constituent priming experiment has been conducted with an elderly population, bearing in mind that research on morphological processing has been scarce in seniors. As indicated in the introduction, Kavé and Levy (2004) tested a group of healthy old Hebrew-speaking participants, and a group of Hebrew patients with Alzheimer's disease, in a cross-modal (auditory prime and visual target) morphological priming experiment. Their results confirmed that both patients and healthy aged participants showed morphological and morphosemantic priming effects (see also Bentin & Feldman, 1990, or Frost et al., 2000). However, the Kavé and Levy results are difficult to generalise because of the very different morphological properties of Hebrew and Indo-European languages (e.g., English, French, Spanish, etc; see Frost et al., 2005b, for extensive discussion) and because Kavé and Levy did not include a control group of young adults. Therefore, the present examination of how age-related changes influence the way in which compound words are recognised and decomposed at the initial stages of lexical access represents a step forward in the literature on morphological priming. Interestingly, the effects obtained were of the same magnitude for both initial and ending position for the young and the elderly. This finding reinforces the view of preserved morphological decomposition and processing in healthy aged individuals, generalising the findings of Kavé and Levy (2004) and Stamatakis and Tyler (2006), at least for transparent compound words.[2]

Not surprisingly, we found longer latencies for the older readers than for the young readers. The general slowing hypothesis (Birren, 1965; Cerella, 1985, 1990) has usually been applied to account for the increase in reading latencies as a function of advanced age. In spite of this increase in reaction times, language processing is thought to be only minimally affected by ageing (e.g., Davidson et al., 2003; Rayner, Reichle, Stroud, Williams, & Pollatsek, 2006; Waters & Caplan, 2005). In the present experiment, we obtained a main effect of group, revealing that reaction times for older adults were longer than for younger adults. Thus, the present results support this view of a general slowing in a direct comparison between young and elder readers. But more importantly, none of the interactions of group with the constituent priming effects resulted significant, revealing that the observed effects did not differ significantly between groups. That is, morphological processing of compound words seems to be fully preserved in aged participants, and hence it is reasonable to conclude that the process of segmentation of a compound word into its constituent lexemes is similar for both groups of readers.

As indicated in the introduction, because of their perceptual and/or cognitive deficits, older adults may be expected to benefit more from

[2] Interestingly, all the previous studies on constituent priming effects in healthy young adults have stated that their results confirmed early morphological decomposition of the compound words (e.g., the lexeme *book* is rapidly identified and processed when a reader encounters the word *BOOKSHOP*). However, it could be thought that the difference in the priming effect obtained from *book-BOOKSHOP* and the unrelated pair *house-BOOKSHOP* may reflect a mere form-based orthographic priming effect. Evidence against this assumption has recently been provided by Duñabeitia, Laka, Perea, and Carreiras (in press-b). Duñabeitia and colleagues showed that constituent priming effects like those from *book-BOOKSHOP* are largely different from orthographic priming effects such as those in pairs like *resta-RESTAURANT*. Further research is needed to test the same subjects with orthographically, morphologically, and semantically related prime-target pairs to test this issue.

contextual support (i.e., from a semantically related prime) than young adults (i.e., a *hyperpriming* effect, as explained by the interactive-compensatory hypothesis; see Laver & Burke, 1993). However, the present findings do not support the idea of hyperpriming in the elderly, at least in the context of morphological priming. In the present experiment, materials were composed of transparent compound words (e.g., *BOOKSHOP*) and all the related primes were not only morphologically linked to the target, but also orthographically and semantically linked (e.g., *book*, *shop*). Hence, because of the high semantic overlap between primes and targets in this experiment, and considering the interactive-compensatory hypothesis and previous results from orthophonological and semantic priming experiments (e.g., Carreiras et al., in press), one might have expected a hyperpriming effect for the elderly group. However, we failed to obtain any signs of an interaction between the magnitude of the effects and the age of the participants (young vs. elderly). Therefore, the present findings cannot be accounted for by the interactive-compensatory hypothesis. Instead, they are better understood in terms of a total preservation of morphological priming effects in healthy aged participants. This pattern of results is consistent with proposals that assume that morphological relationships are much more than a compendium of orthographic and semantic relationships, and that morphemes may have an autonomous representation in the lexicon, (e.g., Aronoff, 1994; Di Sciullo & Williams, 1987; Duñabeitia et al., in press-c; Roelofs & Baayen, 2002; Zwitserlood, Bölte, & Dohmes, 2000, 2002). Of course, we acknowledge that the lack of an interaction between morphological priming and age is a new finding that requires replication—note that a number of prior studies have obtained an additive pattern of semantic priming effects and age (e.g., Balota et al., 1992; Balota & Duchek, 1988; Howard et al., 1981; Ober et al., 1991). What we should note here is that the presence of slow latencies for older adults does not imply that the underlying central cognitive effects are affected, but instead the slow response times may be due to nondecision parameters ("boundary separation" or "nondecision time" rather than "drift rates" in a diffusion model; e.g., see Ratcliff et al., 2004b; Ratcliff, Perea, Colangelo, & Buchanan, 2004a). Thus, the conditions under which hyperpriming can be obtained with elderly readers is a question for further research.

Even though the present results provide the first unambiguous evidence in favour of a preservation of morphological priming effects in the elderly, there are some possible shortcomings of the experiment that should be addressed. First, the neuropsychological performance of only the elderly participants was assessed, since this is the population with higher risk of neuropsychological disorders. However, it could have been of interest to have a psychological assessment for the younger adults (a group of healthy college students). In any case, we conducted a correlation analysis to explore whether the performance across some of the critical neuropsychological tests of the elderly group was related to the constituent priming effects. To this end, net priming effects for the first and second constituents were obtained for each of the elderly participants, and the correlation between these effects and the performance in four critical tests was assessed. These tests were the MMSE test (Folstein et al., 1975), the semantic fluency test (Benito-Cuadrado, Estaba-Castillo, S., Böhm, P., Cejudo-Bolívar, J., & Peña-Casanova, 2002; Spreen & Strauss, 1991), the naming test (based on Snodgrass & Vanderwart, 1980), and the memory test of the RALVT (Rey, 1958). The reason behind this selection is to have a representative test for the screening for dementia (MMSE), and to employ three tests that directly or indirectly measure the linguistic skills of the participants (note that these are the ones most related to the task). As can be seen in Table 3, this analysis did not show any significant correlation between the first/second constituent priming effects and the results in the four tests for the elderly (all $ps > .14$). Therefore, despite some (small) differences in the performance of the elderly participants in the tests that examined their language skills and dementia, these variations did not have a relevant influence on their performance in the experiment. Second, while the use of only transparent compound words as materials has provided a clear picture of morphological processing and ageing, we acknowledge that studying other types of compound may help to complete this picture. Future work should be aimed at exploring how ageing might modulate morphological decomposition effects with opaque, semi-opaque and pseudocompound words (e.g., *deadline*, *strawberry*, and *mayhem*, respectively). For instance, using opaque compounds (i.e., compound words in which the meaning of the constituents is not clearly linked to the whole-word meaning) may shed some light on the morpho-orthographic level of processing, since the semantics of the elements do not completely match, whereas the orthographic representations do.

In summary, the present study has extended previous findings in compound word processing to healthy elderly adults, revealing that morphological processing is unaffected by age as the magnitude of the priming effects was

TABLE 3
Correlation analysis between the net constituent priming effects of the elderly participants and their performance in four critical tests: MMSE, semantic fluency, naming, and the memory test of the RALVT

	MMSE	*Semantic fluency*	*Naming*	*RALVT*
First constituent priming effect	$r = -.12$	$r = .09$	$r = .17$	$r = .18$
	$p = .56$	$p = .67$	$p = .41$	$p = .39$
Second constituent priming effect	$r = .15$	$r = -.05$	$r = .30$	$r = .21$
	$p = .48$	$p = .80$	$p = .15$	$p = .32$

similar for young and old adults. Therefore, meaningful subword units seem to be processed normally by aged participants, at least in the case of transparent, solid compound words.

Original manuscript received October 2007
Revised manuscript received March 2008
Manuscript accepted June 2008
First published online month/year

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