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The role of semantic transparency in the processing of English compound words

Steven Frisson[1]*, Elizabeth Niswander-Klement[2] and Alexander Pollatsek[2]
[1]University of Birmingham, UK
[2]University of Massachusetts, Amherst

Experiment 1 examined whether the semantic transparency of an English unspaced compound word affected how long it took to process it in reading. Three types of opaque words were each compared with a matched set of transparent words (i.e. matched on the length and frequency of the constituents and the frequency of the word as a whole). Two sets of the opaque words were *partially opaque*: either the first constituent was not related to the meaning of the compound (*opaque–transparent*) or the second constituent was not related to the meaning of the compound (*transparent–opaque*). In the third set (*opaque–opaque*), neither constituent was related to the meaning of the compound. For all three sets, there was no significant difference between the opaque and the transparent words on any eye-movement measure. This replicates an earlier finding with Finnish compound words (Pollatsek & Hyönä, 2005) and indicates that, although there is now abundant evidence that the component constituents play a role in the encoding of compound words, the meaning of the compound word is not constructed from the parts, at least for compound words for which a lexical entry exists. Experiment 2 used the same compounds but with a space between the constituents. This presentation resulted in a transparency effect, indicating that when an assembly route is 'forced', transparency does play a role.

Compound words that are in the dictionary differ in how the meanings of the parts relate to the meaning of the compound word. For some compound words, the meaning of both constituents is transparently related to the meaning of the compound word as a whole. In *carwash*, for example, the meaning of the compound word is related to the meaning of both constituents, as it is a place where cars get washed. In contrast, a word like *horseradish* is partially opaque, because, although it tastes similar to a radish, it has nothing to do with horses for most English speakers (although there may be a historical explanation for why horses are associated with this plant). Indeed, compound words can differ in their type of opacity, as there exist compound words composed of two

*Correspondence should be addressed to Dr Steven Frisson, School of Psychology, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK (e-mail: s.frisson@bham.ac.uk).

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constituents for which either the first, the second, or both, constituents can be opaque. (We restrict ourselves to a discussion of two constituent compound words, as they are the type of compounds most often examined in the literature, and were also employed in the present study.) However, we should quickly note that transparency is a relative concept, as even the meaning of transparent compounds cannot be unambiguously computed from the meanings of the constituents. For example, a *clothesline* could also be a line of clothes, or a *woodshed* can either be a shed for storing wood or a shed made out of wood. In addition, a word like *cowboy* is often classified as transparent, even though a cowboy is rarely ever a male human who is young enough to literally be a *boy*.

Investigating compound words that differ in transparency can give us an insight in how language users access a compound word's meaning. If a compound is processed by looking up the compound as a whole (*whole-word model*, e.g. Butterworth, 1983), one does not expect to find any influence of the difference in transparency of the constituent morphemes. On the other hand, if compounds are first decomposed into their constituent morphemes (*morphological decomposition model*, e.g. Taft, 1981), followed by a lookup of those constituents' meaning, and then stitched together again, one would expect that (partially) opaque compounds will be more difficult to process as the attained compound meaning will be odd or anomalous (e.g. *flap* + *jack*) and/or in conflict with the stored whole-word meaning. A third possibility assumes that the processor has access to both the whole-word lookup route and a morphological decomposition route, with semantic transparency possibly playing a role in deciding which route will be used or which one will 'win' (e.g. Baayen, Dijkstra, & Schreuder, 1997; Laudanna & Burani, 1995; Marslen-Wilson, Tyler, Waksler, & Older, 1994; Pollatsek, Hyönä, & Bertram, 2000).

While it is commonly accepted that 'semantic transparency should play a prominent role in any model of compound representation and processing' (Libben, 1998, p. 35), the evidence for semantic transparency effects is mixed (see below). In addition, due to the diversity of tasks employed in compound processing research, it is often unclear at what *stage* in processing semantic transparency plays a role and/or whether some of the reported effects might be task induced. On the basis of the existing evidence, and building on the work of the processing of other complex words, we suggest that a distinction is necessary between an early visual processing stage, in which words are automatically morphologically decomposed (with meaning arguably playing no role), and a later stage that might be sensitive to semantic transparency.

Evidence that decomposition plays a role at the earliest stages of compound processing comes from both eye-movement studies and lexical decision tasks using constituent priming. In both Finnish (Bertram & Hyönä, 2003; Hyönä & Pollatsek, 1998, 2000; Pollatsek *et al.*, 2000) and English (Andrews, Miller, & Rayner, 2004; Juhasz, Inhoff, & Rayner, 2005; Juhasz, Starr, Inhoff, & Placke, 2003), it has been shown that the frequency of the constituents plays an active role in encoding, which is what one would expect if the compound is being decomposed in its constituent morphemes. These frequency effects were apparent on *gaze duration*, the sum of the durations of all fixations on the word on the first pass through the text, and sometimes even on the first fixation on the compound word[1]. In addition to these constituent frequency effects, the

[1] *More precisely, for both first-fixation and gaze durations, the 'first-pass' fixations only include fixations before any text beyond the target word is fixated. They also do not include any fixations after the target word has been left (either by a forward saccade or a regression). In addition, if the word is initially skipped, this datum is not included in the mean fixation duration.*

frequency of the entire compound plays a role as well (e.g. Bertram & Hyönä, 2003; Pollatsek *et al.*, 2000), indicating that compound recognition is not merely a matter of identifying the constituents and then assembling them. Niswander-Klement and Pollatsek (2006) observed similar whole-word frequency and root frequency effects on English prefixed words.

Further evidence for the activation of individual constituents comes from constituent priming studies, in which a constituent of the compound is either employed as a prime or a target. Overall, these studies show reliable priming effects, again suggesting that decomposition occurred at some level (e.g. Jarema, Busson, Nikolova, Tsapkini, & Libben, 1999, Experiment 1; Libben, Gibson, Yoon, & Sandra, 2003; Monsell, 1984; Zwitserlood, 1994, Experiment 1). Interestingly, these studies also showed that priming effects were apparent for both transparent and opaque compounds, which indicates that even opaque compounds can undergo decomposition. These results are in line with recent work on the processing of affixed words. Using the masked priming technique, Rastle and colleagues (e.g. Rastle, Davis, Marslen-Wilson, & Tyler, 2000; Rastle, Davis, & New, 2004; see also Longtin, Segui, & Hallé, 2003; Marslen-Wilson & Tyler, 2000) found priming effects both for stems that *were* (e.g. cleaner, CLEAN) or *appeared* to be (e.g. corner, CORN) morphologically related to their primes. The semantic relationship between the masked prime and the target did not affect the size of the priming effect, though transparency effects did become apparent when the SOA was long. We will return to this issue in the Discussion.

The priming results with a long SOA for affixed words seem to support the hypothesis that the semantic transparency or opacity of a compound affects a later stage of processing. There is also some evidence that suggests that opaque and transparent compounds are processed differently. Sandra (1990) used semantic priming in a lexical decision task and found priming effects for transparent Dutch compounds, though not for (partially) opaque compounds (e.g. *moon* as a prime for *SUNDAY*). Zwitserlood (1994, Experiment 2), using transparent, partially opaque and opaque Dutch compounds as primes and semantic associates as targets in a lexical decision task, found priming effects for transparent and partially opaque compounds, but not for fully opaque ones. Libben *et al.* (2003) showed different processing patterns for compounds with a transparent morphological head (i.e. in English, compounds with a transparent second constituent: TT, transparent–transparent and OT, opaque–transparent compounds) compared with compounds with an opaque head (OO, opaque–opaque and TO, transparent–opaque compounds). Their first experiment employed a lexical decision task in which the compounds were presented as either one word or two words. Participants saw both versions on different trials, which allowed the researchers to measure the effect of repeating the compound. They observed longer response times to compounds with an opaque head, although this result could at least partially be explained by frequency differences[2]. They also found that compounds with an opaque

[2] *In addition to the TT compounds having a higher whole-word frequency than the other compound types, a search also revealed that the frequency of the first constituent was three to eight times higher for the TT and the OT compounds (average frequency of the first compound: 168 for TT, 79 for OT, 25 for TO and 19 for OO; based on Francis & Kučera, 1982). We think that this frequency imbalance might have affected not only the overall lexical decision latencies but possibly also the repetition effects. Libben* et al. *(2003) showed that compounds with an opaque head exhibited much stronger repetition effects than compounds with a transparent head. However, given that low-frequency words, in general, show stronger repetition effects than high-frequency words (e.g. Forster & Davis, 1984), it is unclear to what extent the reported repetition effects were caused by differences in opacity or differences in frequency.*

head showed stronger repetition effects when the compound was presented as two separate words. In Experiment 2, a lexical decision task in which either constituent was primed for 150 ms, both initial and final constituents primed all compound types, which is in line with the evidence discussed previously. In addition, they also found that, again, compounds with an opaque head benefited more from repetition than compounds with a transparent head.

Underwood, Petley, and Clews (1990), who examined fixation times on words when people read sentences, compared English transparent and opaque compounds with each other (it is unclear whether the opaque compounds were fully or only partially opaque). The compounds appeared in one of four conditions: the context primed either the first constituent, the second constituent, the whole compound or was neutral. They found a main effect of transparency, with the opaque compounds being read about 29 ms slower in gaze duration, and no interaction with context type. However, as the authors acknowledged (p. 202), the contexts were not controlled for predictability, which might have affected the results. In fact, when looking at the neutral context condition separately, the difference between the opaque and the transparent compounds was a mere 3 ms. It is therefore unclear whether compound opacity plays a role in normal reading. Pollatsek and Hyönä (2005) found no convincing evidence of a transparency effect in eye-tracking. They employed Finnish compound words, and used a design in which the frequency of the first constituent and the transparency of the compound word were factorially varied. In three experiments, they obtained effects of first constituent frequency (indicating that componential processing was occurring), but obtained no effect of semantic transparency. This was quite a surprising finding as compounding is very productive in Finnish and thus a typical Finnish reader encounters several novel compounds everyday, and the meaning of these novel compounds must be computed from the constituents[3].

To summarize, there is now quite a large amount of evidence, both from lexical decision and eye-movement studies, that the individual constituents of a compound play a role in early processing. In addition, the level of transparency of the compound does not seem to be a factor at this stage of processing. The evidence that transparency affects other stages of processing is mixed. Sandra (1990) did not find semantic priming effects for partially opaque compounds (most of them OT compounds), while Zwitserlood did find priming effects for partially opaque compounds but not fully opaque ones. Pollatsek and Hyönä (2005), using eye-tracking, did not find evidence of a transparency effect with fully and partially (OT) opaque compounds. Libben *et al.* (2003) found that compounds with an opaque head (OO and TO compounds in English) were processed differently from compounds with a transparent head (TT and OT).

As we thought that the prior results on processing compound words in reading using eye-movement measures were not conclusive because the type of opaque word was not controlled, the present experiments employed the four different kinds of compounds: TT (*cookbook*), OT (*restroom*), TO (*heirloom*) and OO (*cocktail*). As indicated previously, although Pollatsek and Hyönä (2005) found no transparency effects for Finnish compounds, they did not systematically manipulate the type of opaque compound word they used (they employed a mix of OO and OT compounds), and there may be different effects of opacity depending on which constituent was opaque (cf. Zwitserlood's results). It might also be possible that Finnish constitutes a special

[3] *In English, readers encounter novel compounds relatively often as well, though they tend to be spaced compounds.*

case. As pointed out above, compounding is extremely pervasive in Finnish and, at least in theory, it might be that Finnish language users have developed special strategies to deal with this abundance. For example, they might want to keep the meaning computation, based on the individual constituents' meanings, to a minimum by always using the compound meaning if available. While we think this possibility is doubtful, it cannot be ruled out beforehand. Finally, as the reading data of Pollatsek and Hyönä are at odds with the studies using other measures (like lexical decision response times), it would be valuable if we can replicate (or disconfirm) their results with different stimuli in a different language using the same technique.

EXPERIMENT 1

The goal of the experiment was twofold. First, we wanted to find out whether partially opaque and fully opaque compounds are processed differently from entirely transparent compounds. Second, we wanted to examine whether the position of the opaque constituent (first vs. second) affects processing. If our reading data mirror the Finnish data from Pollatsek and Hyönä (2005), there would be no difference between transparent and OT or OO compounds. If their findings extend to TO compounds (which they did not test), then we also do not expect to find a difference between TO and TT compounds. In contrast, Sandra's (1990) data suggest that we should find a difference between TT and OT compounds, while Zwitserlood's (1994) data predict a difference between TT and OO compounds, but not between TT and partially opaque compounds. Libben *et al.*'s (2003) data suggest that compounds with a transparent head (TT and OT) will not differ from each other, while compounds with an opaque head (OO and TO) will be processed differently from TT compounds.

Method

Participants

Forty-four native American English-speaking students from the University of Massachusetts were paid $8 to participate in the experiment. All had normal or corrected-to-normal vision and none participated in the pre-test (see below).

Materials

There were a total of 34 (partially) opaque compounds, divided into three sets: 10 had an opaque first constituent and an opaque second constituent (OO), 14 had an opaque first constituent and a transparent second constituent (OT) and 10 had a transparent first constituent and an opaque second constituent (TO). Each compound was paired with a fully transparent compound (TT). For each compound pair, we wrote a matrix sentence that was exactly the same except for the compound itself. Examples can be found in (1)–(3), with the transparent control word in parentheses. All experimental items are listed in the Appendix.

(1) Jane always had a cocktail (cookbook) on the counter when she was preparing dinner (OO).
(2) Harry told the girl in the cloakroom that his trenchcoat (raincoat) was brown, brand new and very expensive (OT).

(3) The police were summoned after the heirloom (mailbag) had been reported missing (TO).

The transparent and the opaque compounds in each set were matched as closely as possible for the length and frequency (based on the CELEX database; Baayen, Piepenbrock, & Van Rijn, 1995) of the first and the second constituents individually, and for the compound as a whole (see Table 1). A pre-test was carried out in order to assess the perceived transparency of the constituents.

Pre-test: Transparency judgments

Forty participants rated the transparency of 182 compounds. They were asked to indicate, for each constituent separately, whether its meaning was transparently related to the meaning of the compound as a whole or not. On the basis of this pre-test, we created four sets of compounds: OO, OT, TO and TT. There was good agreement on the appropriate categorization of the compounds that were used in the experiment below; for the selected compounds, the percentage of time that people's choices agreed with the nominal classification (e.g. for a TO word, the first constituent was classified as transparent and the second constituent as opaque) was 65% for OO, 71% for OT, 65% for TO, and 85% for TT1, 84% for TT2 and 88% for TT3. Moreover, the percentage of time that people classified at least one of the constituents as opaque for the opaque words was very high: 95% for OO, 93% for OT and 95% for TO, and the percentage of the time that they classified the head noun as opaque was 91% for TO compounds and 84% for OO compounds. The percentage of time that the modifier noun was classified as opaque was: 92% for OT, 90% for OO, 18% for TO and 11% for TT compounds.

The experimental items were divided into two lists so that each participant saw only one version of each compound pair, and an equal number of (at least partially) opaque and transparent compounds per set. The 34 sentences were mixed with 99 filler items of various types (these were items from other experiments that resembled the target sentences in length and structure, but generally did not contain compounds). The sentences were presented in a fixed random order.

Procedure

Participants were tested individually in a dimmed room. Eye-movements were recorded using a Fourward Technologies Dual Purkinje Generation 5 eye tracker, which has an angular resolution of less than 10 minutes of arc. Sentences were displayed on a single or two lines with a maximum length of 80 characters (the target regions all appeared on the first line). Viewing was binocular but only the eye-movements of the right eye were monitored. Stimuli were displayed on a 15 inch NEC 4FG colour monitor 61 cm from the participants' eyes. (At this distance, 3.8 character positions equalled 1° of visual angle.) Participants' gaze position was recorded every millisecond. A bite bar and forehead rest was used in order to minimize head movements.

Participants were encouraged to read the sentences carefully for understanding and to read at a normal rate. At the start of the experiment, a calibration procedure was carried out, and calibration checks were performed before the start of each sentence. If the check was unsatisfactory, a recalibration was performed. After finishing reading a sentence, participants pressed a button to remove the sentence. Comprehension questions appeared after 50% of the items (balanced across conditions), and the

Table 1. Item characteristics

	Length			Word log frequency			Lemma log frequency		
Type of word	Whole word	Const. 1	Const. 2	Whole word	Const. 1	Const. 2	Whole word	Const. 1	Const. 2
All sets combined									
Opaque	8.7	4.7	4.0	1.1	2.4	2.6	1.3	2.6	2.8
Transparent	8.8	4.5	4.3	1.2	2.7	2.7	1.2	2.9	2.9
Set 1									
OO	8.6	4.2	4.4	1.4	2.4	2.8	1.6	2.5	2.9
TT1	8.6	4.2	4.4	1.4	2.6	2.6	1.5	2.8	2.8
Set 2									
OT	8.6	4.6	4.0	0.9	2.4	2.6	1.0	2.7	2.9
TT2	8.6	4.6	4.0	1.1	2.7	2.9	1.2	2.9	3.1
Set 3									
TO	8.9	5.1	3.8	1.1	2.5	2.2	1.3	2.5	2.5
TT3	9.1	4.6	4.5	1.0	2.8	2.6	1.1	2.9	2.7

answers were indicated by a button press. Half of the questions required a *yes* response, half a *no* response. The comprehension questions were answered correctly 96.7% of the time.

Analyses

We report analyses on two regions: the compound word (excluding any determiners) and a *spillover* region. The spillover region was defined as the word following the target word if that word was five or more characters or the two words following the target word if the first was four or fewer characters. For one item, the spillover region coincided with the end of the line and was therefore not included in the spillover analysis.

An automatic software procedure pooled short contiguous fixations: fixations shorter than 80 ms that were within one character of another fixation were incorporated into one larger fixation under the assumption that they were a single fixation in which the eye moved a bit. Fixations shorter than 80 ms and not within one character space of another fixation were deleted as, presumably, readers hardly extract any information during these short fixations (see Rayner & Pollatsek, 1989).

The following reading measures were analysed: *first-fixation duration* (the duration of the first fixation on a region, *single-fixation duration* (the fixation time on a region when the region is fixated only once), *gaze duration* (the combined fixation time on a region before fixating on another word) and *first-pass regressions* (the percentage of leftward eye-movements that cross a region's left boundary that immediately follow a first-pass fixation). In addition, we report *regression-path duration* (the summed fixation times starting when entering a region until the region's right boundary is crossed, this measure includes fixations to the left of the region if there are any) as a measure of 'later' or 'deeper' processing. (First-fixation duration, single-fixation duration and gaze duration are all conditional on the region being fixated and subsequent text not being fixated prior to the word being fixated for the first time.) We set the low cut-off at 100 ms and the high cut-off at 800 ms for all reading time measures (except regression-path duration, where we set the maximum cut-off at 2,000 ms), and these trials were deleted from all analyses in order for the analyses to properly relate to each other. In addition, all sentences with major track losses and sentences for which the sentence fragment preceding the compound was not fixated in the first pass were excluded. In total, 7.2% of the data was excluded.

Results and discussion

For each measure and each region, the data were subjected to separate transparency (transparent vs. opaque) × set (OO vs. OT vs. TO) ANOVAs, treating participants (F_1) and items (F_2) as random effects. Both factors were treated as within-participant variables; however, transparency was treated as within-item variable and set as a between-items variable. If (partially) opaque compounds behave differently from fully transparent ones, then we should find a main effect of transparency. If the different types of compounds are resolved differently, we expect to find an interaction of transparency and set. A main effect of set is not as interesting as the sentence frames were different for the three different sets. Table 2 presents the averages, using participant means. We discuss each region separately.

Table 2. Experiment 1: mean reading time durations (in ms) and percentage of first-pass regressions on the compound and the spillover region

	Transparency condition					
Measure of processing	OO	TT1	OT	TT2	TO	TT3
Gaze duration						
Compound	365 (12.7)	365 (12.7)	377 (13.3)	362 (12.1)	387 (13.5)	394 (12.8)
Spillover	388 (12.3)	391 (13.9)	347 (11.3)	342 (10.1)	344 (12.2)	332 (11.6)
First-fixation duration						
Compound	291 (7.8)	297 (8.2)	297 (8.6)	287 (8.1)	296 (7.3)	289 (7.3)
Spillover	300 (7.6)	284 (6.4)	294 (7.5)	288 (6.5)	283 (8.4)	287 (9.2)
Single-fixation duration						
Compound	315 (9.3)	323 (11.9)	319 (10.8)	318 (9.4)	309 (11.2)	305 (10.1)
Spillover	313 (8.8)	296 (9.0)	311 (9.8)	300 (6.7)	301 (12.3)	301 (10.5)
First-pass regressions						
Compound	9.5 (2.5)	12.7 (2.8)	12.1 (2.4)	13.8 (2.8)	10.8 (2.6)	11.7 (2.4)
Spillover	3.4 (1.2)	4.4 (1.5)	5.6 (1.5)	2.6 (0.8)	4.1 (1.4)	5.0 (1.7)
Regression-path duration						
Compound	413 (14.5)	424 (16.0)	464 (22.8)	435 (22.0)	470 (22.2)	461 (22.5)
Spillover	440 (17.6)	443 (23.8)	387 (15.5)	363 (12.3)	379 (18.4)	358 (15.1)

Note. OO: opaque–opaque compound, TT1: transparent–transparent control for OO; OT: opaque–transparent compound, TT2: transparent–transparent control for OT; TO: transparent–opaque compound, TT3: transparent–transparent control for TO. Reading times are given in milliseconds, first-pass regressions are in percentages. Standard errors are presented in parentheses.

Compound word region

First, consider the global measure of first-pass processing, gaze duration. As can be seen in Table 2, there was virtually no overall effect of transparency (3 ms averaged over the three sets), Fs < 1. There was a main effect of set in the participants analyses, $F_1(2, 86) = 5.63$, $p < .01$; $F_2(2, 31) = 1.93$, $p > .15$, as the items of the TO–TT3 set exhibited slightly longer reading times, which might be related to the fact that these items were somewhat longer as well (see Table 1). However, there was no interaction of transparency with set, Fs ≤ 1, and even the 15 ms difference between OT and TT2 was not close to significant when analysed separately, $t(43) = 1.65$, $p > .10$, $t(13) < 1$. A similar picture emerged for the other fixation duration measures on the compound word. For first-fixation duration, the main effect of transparency was also 3 ms and there were no significant main effects or interactions (all Fs < 1.2). Neither the 10 ms difference between the OT items and their controls nor the 7 ms difference between the TO items and their controls was close to significant: $t(43) = 1.31$, $p = .20$; $t(13) = 1.06$, $p > .30$, ts < 1, respectively. Similarly, there were no effects in the single-fixation duration analyses that were close to significant (all ps $> .12$), and the 8 ms difference between OO and TT1 was not significant (ts ≤ 1). It should be noted that there were actually more first-pass regressions out of the compound word region for the transparent words (1.9 averaged over the three sets), although again, none of the differences were significant (all Fs < 1.4). The regression-path analyses, which arguably reflect more deliberate processing, also showed no transparency effect (9 ms difference overall: Fs < 1). The main effect of set was significant in the participants analyses only: $F_1(2, 86) = 5.33$, $p < .01$; $F_2(2, 31) = 1.46$, $p > .20$, and there was no interaction:

*p*s $> .18$. Means comparisons showed no differences between the OO and the TO compounds compared with their respective controls (*t*s < 1). The 29 ms difference between OT and its control also failed to reach significance: $t(43) = 1.96$, $p = .06$; $t(13) = 1.04$, $p > .30$.

Spillover region

Gaze duration analyses showed an effect of set, $F_1(2, 86) = 26.43$, $p < .001$; $F_2(2, 30) = 3.06$, $p = .06$, but as the spillover regions differed between the sets, this result is not very informative. More importantly, there was no effect of transparency (5 ms on average, *F*s < 1), no interaction (*F*s < 1), and none of the three pairwise comparisons approached significance (all *t*s < 1). For first-fixation duration on the spillover region, the 6 ms transparency main effect was not significant: $F_1(1, 43) = 2.06$, $p = .16$; $F_2(1, 30) < 1$, nor was there an effect of set: *F*s < 1. However, there was a weak interaction: $F_1(2, 86) = 1.98$, $p = .14$; $F_2(2, 30) = 2.85$, $p = .07$. First-fixation durations on the spillover region for OO compounds were 16 ms longer than for their TT controls, which was marginally significant, $t(43) = 2.52$, $p < .02$; $t(8) = 2.12$, $p = .07$, whereas there was only a 6 ms effect for the OT vs. TT2 difference, *t*s < 1, and actually a -4 ms difference for TO vs. TT3: $t(43) < 1$, $t(9) = -1.98$, $p = .08$. For the single-fixation analyses, the 9 ms transparency effect was also not significant: $F_1(1, 39) = 1.70$, $p = .20$; $F_2(1, 30) < 1$, nor did we observe a main effect of set (*F*s < 1) or a significant interaction: $F_1(1, 39) < 1$; $F_2(2, 30) = 2.10$, $p = .14$. The pattern of differences was similar to that in the first-fixation duration analyses, with differences of 17, 11 and 0 ms, for the OO, OT and TO compounds, respectively. (all *p*s $> .08$). None of the analyses on the number of first-pass regressions from the spillover region approached significance (all *p*s $> .28$). It is worth mentioning that, although the effects for first- and single-fixation durations in the spillover region are suggestive of a transparency effect for the OO compounds, the gaze duration effect in the spillover region for the OO compounds was -3 ms (see Table 2). Finally, the regression-path duration analyses showed an effect of set: $F_1(2, 86) = 19.69$, $p < .001$; $F_2(2, 31) = 2.97$, $p < .07$; no effect of transparency: $F_1(1, 43) = 2.14$, $p = .15$; $F_2(1, 30) = 1.19$, $p > .28$ and no interaction: *F*s < 1. Means comparisons again showed no significant effects: *p*s $> .15$.

The above analyses indicate that transparency of a compound is having little effect on the time to process that compound, both when looking at more immediate and later measures of processing. However, one might worry about a power problem for making a definitive statement with respect to a particular type of compound because there were not all that many compounds in each of the sets and because exact agreement on the type of compound by the raters was not that high.[4] To remedy this problem, we conducted separate analyses only on the compounds that had an opaque head (TO and OO) because the opaqueness of the head is claimed to be the chief determiner of transparency effects (Libben *et al.*, 2003). As should be clear from the above presentation, however, the effects were generally small and none were significant (for all measures on both the compound and the spillover region: all

[4] *As there is no data on how participants classified the items in the other compound experiments reported, we do not know how our ratings compare with theirs. However, given that there was a considerable overlap between our items and those used in Libben* et al. *(2003), we do not think that our items (and ratings) are in any significant way deviant from those studied previously.*

ts < 1.19, all ps $> .24$). Moreover, they even do not all point in the same direction. The combined effects of OO and TO vs. their transparent controls were: (a) -3 and 4 ms for gaze duration on the compound word and spillover region, respectively; (b) 1 and 6 ms for first-fixation duration on the compound word and spillover region, respectively; (c) -2 and 8 ms for single-fixation duration on the compound word and spillover region, respectively; (d) -2.1% and -1.0% for the percentage of regression from the compound word and spillover region, respectively and (e) -1 and 9 ms for regression-path duration on the compound word and spillover region, respectively (see Table 2).

Regression analysis on gaze durations

We also performed a regression analysis on the gaze duration item means to be sure that there was not a possible transparency effect we were missing. First, because prior research (Bertram & Hyönä, 2003; Niswander-Klement & Pollatsek, 2006) has indicated that componential processing is more in evidence for longer compound and prefixed words than for shorter compound and prefixed words, we wanted to determine whether there was evidence that there was a transparency effect modulated by word length. Second, because several indices of the words were closely, but not perfectly, matched between opaque and transparent words, we wanted to be sure that these small differences were not masking an effect of transparency. Accordingly, in the regression analysis over all 34 item pairs, the dependent variable was the difference in gaze duration on the target word between a transparent–opaque pair of words, and the predictors were: average length of the two words, difference in length between the two words, difference in log frequency of the first constituent between the two words and difference in log frequency of the second constituent between the two words. In fact, the regression analysis revealed no hidden transparency effect. First, although the regression analysis indicated an increase of about 5 ms in the transparency effect per letter, the reliability of this effect was minimal ($t = 0.5$). Second, the best estimate from this analysis of the size of the 'true' transparency effect (i.e. when the other variables are controlled for) for compounds with the same length as the mean length of the compounds in the study, was 6 ms, about the same as that reported previously. (The only predictor variable that had a significant effect was the difference in length between the two words, merely indicating that longer words have longer gazes.)

As our conclusions rest on null results, there is of course always the possibility that our transparency manipulation was not sufficiently powerful to demonstrate an effect. We therefore ran a second eye-tracking experiment with the same sentences, though with the compounds in a different format: there was a space between the constituents. By presenting the compounds as two separate words, we presumably 'force' the use of a decomposition route and inhibit a direct lookup route, thereby hampering the processing of opaque compounds more than that of transparent compounds because the meaning of the constituents of an opaque compound cannot easily be reassembled to give the meaning of the compound as a whole. In line with this hypothesis, Libben *et al.* (2003, Experiment 1), using a lexical decision task, found that when compounds were presented as two separate words, opaque compounds took longer than transparent compounds. More specifically, in Libben's data, all three types of opaque compounds showed longer response times than their transparent controls and the three transparent controls had approximately equal response times.

EXPERIMENT 2

The aim of this experiment was to test whether transparency effects can be observed with the same set of compounds when presented as two separate words. If this is the case, then it is difficult to argue that the null results from Experiment 1 were due to a lack of power in the items set.

Method

Participants

Twenty-four students from the University of Birmingham, UK, were paid to participate in the experiment. All had normal or corrected-to-normal vision.

Materials

The same sentences as in Experiment 1 were used, except that the compounds were spelled with a space between the two constituents. The items were divided over two lists and mixed with 90 items from different experiments. Comprehension questions were asked after 50% of the items. Accuracy for the questions was 95.8%

Procedure

Participants were tested individually on an SR Research Eyelink II eye tracker and presentation software. The eye tracker sampled eye position every 2 ms. Viewing was binocular, but only data from the eye that was calibrated best was used in the analyses. Screen resolution was set at 1,024 by 768 pixels and participants were seated 70 cm from the screen. Sentences were displayed in Times New Roman font 18 pt size. With this set-up, 1° of visual angle equals about 3.5 characters. Using the Times New Roman font did not alter the word length matching as both transparent and opaque compounds occupied 37 mm of text on the screen on average (including the space between the two words), $t < 1$. The length for the different condition pairs also did not differ significantly (all ps $> .25$). A chin rest was used to minimize head movements.

A calibration procedure was performed at the beginning of the experiment and repeated whenever the experimenter felt necessary. Before each trial, a fixation point coinciding with the first letter of the upcoming sentence appeared on the screen. Participants fixated this point, an automatic drift correction was performed, and the sentence was displayed. After reading a sentence, participants pressed a button on a hand-held game console and the sentence disappeared, followed either by a question or by the fixation point. Questions were answered by pressing one of the two buttons on the console.

Analyses

Short fixations (less than 80 ms) were treated in the same way as in Experiment 1. Cut-off values were set at 100 and 1,200 ms (2,000 ms for the regression-path analyses). The upper limit was slightly increased because rather than one word, the compound region now spanned two words. Analyses with a lower or higher cut-off did not change the pattern of results. Sentences with major track losses and sentences for which the region up to the compound was not fixated in first pass were excluded. In total, 9.5% of the data was excluded from the analyses.

Results and discussion

The same analyses were carried out as for Experiment 1. Table 3 presents the averages, using participant means.

Table 3. Experiment 2: mean reading time durations (in ms) and percentage of first-pass regressions on the compound and the spillover region

	Transparency condition					
Measure of processing	OO	TT1	OT	TT2	TO	TT3
Gaze duration						
Compound	356 (19.0)	344 (16.3)	355 (13.8)	333 (14.4)	368 (21.9)	357 (15.5)
Spillover	388 (22.9)	340 (16.6)	319 (16.7)	269 (9.8)	281 (17.8)	262 (12.8)
First-fixation duration						
Compound	226 (9.2)	220 (6.9)	227 (7.6)	219 (6.3)	239 (8.9)	224 (7.3)
Spillover	248 (11.6)	238 (9.6)	233 (8.5)	224 (6.0)	228 (8.9)	218 (8.6)
Single-fixation duration						
Compound	236 (14.3)	240 (18.8)	219 (14.3)	217 (11.6)	248 (17.7)	235 (25.2)
Spillover	255 (15.5)	247 (13.0)	239 (10.8)	225 (6.8)	237 (15.2)	223 (11.2)
First-pass regressions						
Compound	12.8 (3.4)	17.2 (4.3)	15.3 (3.6)	15.9 (4.3)	22.9 (5.5)	15.2 (3.3)
Spillover	16.0 (4.0)	14.5 (3.5)	11.7 (3.1)	8.9 (2.4)	7.3 (2.2)	4.8 (2.5)
Regression-path duration						
Compound	428 (23.0)	440 (27.2)	422 (21.7)	409 (17.4)	494 (28.2)	431 (23.7)
Spillover	490 (34.0)	425 (28.1)	399 (26.0)	319 (15.8)	327 (20.8)	290 (20.0)

Note. OO: opaque–opaque compound, TT1: transparent–transparent control for OO; OT: opaque–transparent compound, TT2: transparent–transparent control for OT; TO: transparent–opaque compound, TT3: transparent–transparent control for TO. Reading times are given in milliseconds, first-pass regressions are in percentages. Standard errors are presented in parentheses.

Compound word region

Gaze duration here is defined as the sum of first-pass fixations on the entire compound word region to be comparable with the gaze durations in Experiment 1. In fact, the gaze durations showed a small transparency effect, with the transparent items being read 15 ms faster on average; however, this effect was only marginally significant in the participants analysis: $F_1(1, 23) = 3.15$, $p < .09$; $F_2(1, 31) < 1$. No other effects approached significance (all ps $> .32$). There were no significant transparency effects on either first-fixation duration (all ps $> .11$), single-fixation duration (all ps $> .27$) or on first-pass regressions (all ps $> .13$). The regression-path analyses showed a main effect of set which was only significant in the participants analysis: $F_1(2, 46) = 4.59$, $p < .05$; $F_2(2, 31) = 1.30$, $p > .28$ and no other effects (ps $> .18$).

Spillover region

A significant effect of transparency was found in the gaze analyses, as gazes on the spillover regions following the opaque items were 39 ms longer than gazes on the same regions following the transparent items: $F_1(1, 23) = 9.96$, $p < .01$; $F_2(1, 31) = 21.01$, $p < .001$. In addition, a significant main effect of set was observed [$F_1(2, 46) = 44.83$, $p < .001$; $F_2(2, 31) = 5.38$, $p = .01$], although, as argued previously, this is not very informative as the spillover regions were not controlled across the different types. However, the interaction between set and transparency, which would reveal whether the transparency effect was different for the three types of opaque compounds, was not close to significant ($ps > .15$). There was a 9 ms effect of transparency on the first-fixation duration in the spillover region which was marginally significant in the participant analysis, $F_1(1, 23) = 3.10$, $p = .09$; $F_2(1, 31) = 1.91$, $p > .17$, There was a marginal effect of set, $F_1(2, 46) = 4.41$, $p < .05$; $F_2(2, 31) = 2.83$, $p = .07$, but the set by transparency interaction was not significant ($Fs < 1$). No effects emerged on the single-fixation analyses (all $ps \geq .10$). The only effect in first-pass regressions that was close to significant was a main effect of set, $F_1(2, 46) = 5.81$, $p < .01$; $F_2(2, 31) = 2.63$, $p < .09$ (all $ps > .39$ in the other analyses). The regression-path analyses revealed a significant main effect of transparency, with the transparent items being read 61 ms faster on average: $F_1(1, 23) = 10.13$, $p < .01$; $F_2(1, 31) = 12.72$, $p < .001$. In addition, there was a main effect of set [$F_1(2, 46) = 31.40$, $p < .001$; $F_2(2, 31) = 6.22$, $p < .01$], but no interaction ($Fs < 1$).

The results indicate that a transparency effect can be found for the same items when they are presented as two separate words. This effect appeared to be slightly delayed – in the gaze data on the spillover region. This should come as no surprise as one would expect that reassembling the meaning of the compound from its constituents' meaning should take time, especially if the original meanings have to be rejected, as is the case for the opaque compounds.[5] Hence, it is unlikely that the lack of a transparency effect in Experiment 1 was caused by an idiosyncratic item set.

We also performed combined analyses on the data of Experiments 1 and 2. If the transparency effect that was found in Experiment 2 is indeed significantly different from the (lack of a) transparency effect in Experiment 1, then we would expect to observe an interaction between experiment and transparency. For the gaze duration data, a 2 (experiment: Experiment 1 vs. Experiment 2) × 2 (transparency: transparent vs. opaque) ANOVA on the spillover region, treating the factor experiment as between-participants and within-items, showed exactly such an interaction: $F_1(1, 202) = 6.38$, $p = .01$; $F_2(1, 32) = 13.70$, $p = .001$. Similarly, a reliable interaction was found for the regression-path data on the spillover region: $F_1(1, 202) = 5.30$, $p < .05$; $F_2(1, 32) = 4.67$, $p < .05$. These analyses strongly indicate that the compounds were indeed processed differently in both experiments, with transparency only playing a role when normally unspaced compounds are presented with a space.

One concern with the present results is that using the same sentences as in Experiment 1, some items might have caused a temporary semantic garden-path if readers processed the sentences strictly incrementally (though see Frisson, Pickering, & McElree, 2003, for evidence against strict incrementality). For example, the sentence *Jack bought a pocket* is odd without the second constituent *knife*. However, we do not think this can explain the transparency effect as, according to our intuitions, the potential for this type of semantic garden-pathing only occurred infrequently and was evenly distributed between the opaque and the transparent compounds (six times each). A second concern relates to the spelling of the compounds. While all our compounds were spelled as one word in the dictionary, there seems to be some

[5] *Note that the reading times for the spaced compounds were not noticeably longer than for their one-word counterparts of Experiment 1 (a difference observed by Libben* et al.*, 2003). But this comparison is unwarranted as both the participants and item presentation differed from Experiment 1. Nevertheless, this has no bearing on the reported pattern of results.*

confusion amongst English spellers as to when a compound is written as one word, with a hyphen or as two separate words. In general, transparent compounds are more likely to be written as two words and therefore it might have been the case that the transparency effect reflects a difference in spelling preference rather than a semantic composition effect. We asked a further 20 students from the University of Massachusetts to indicate how they would spell our compounds: as one word, two words or with a hyphen. Not surprisingly, the transparent compounds were spelled as individual words more often than the opaque compounds [32.2% vs. 14.4%, $t(33) = 5.20$, $p < .001$]. However, this difference might also reflect a more deliberate strategy employed by the participants rather than a true spelling preference: if the meaning of a compound is transparent, then it is more likely to be written as two words; hence, when faced with a transparent compound, participants will be more likely to choose that spelling. Nevertheless, we decided to correlate the difference in spelling preference (i.e. the difference in probability that a certain compound is spelled as two words) with the difference scores between the transparent and the opaque compounds for the three condition pairs. For the two measures where we found a significant effect of transparency, gaze duration and regression-path duration, none of the correlations approached significance: all rs $< .13$, all ps $> .47$. Hence, the transparency effect is not related to off-line spelling preferences.

GENERAL DISCUSSION

Our data from Experiment 1 indicate that there was virtually no effect of semantic transparency in the processing of compound words in English during normal reading. The largest difference in the gaze duration data and the regression-path duration data was not significant and on the 'wrong' set, the OT compounds for which the second constituent, the *head*, was transparent. That is, one would expect the least problem for these opaque compounds because an approximate meaning of the word is given by the transparent head (e.g. *strawberry* is a type of *berry*, see also Libben *et al.*, 2003). For the other two sets, in which the head was opaque, and for which even an approximate meaning of the compound is unlikely to be computable from the constituents, there was absolutely no evidence for a transparency effect. The only transparency effect that approached significance was on the duration of the first fixation on the spillover region for the OO opaque words. However, as indicated previously, it is necessary to exercise caution with this marginal effect as: (a) the gaze duration on the spillover region was actually slightly longer for the transparent controls than the OO opaque words and (b) there were more regressions back from this region for the transparent controls than from the OO opaque words, which might have shortened the average fixation durations. Thus, there is no convincing evidence from these data that readers are computing the meaning of the compound word from its constituents for English compound words in the lexicon.

Experiment 2 demonstrated that the same items, when presented with a space between the two constituents, did show a transparency effect. This makes sense because when a compound is presented as two separate words, it is more likely that a decomposition route will be taken (i.e. accessing the meaning of the individual words, followed by integrating the two meanings). Thus, if the compound is transparent, this integration will be rather straightforward; however, if the compound is (partially) opaque, the attempted integration of the meanings will result in a semantic anomaly and the integrated meaning will have to be rejected and a (stored) whole-word meaning will have to be accessed. Our results indicate that this process takes some time to complete as the differences between spaced opaque and transparent words first appeared in the gaze durations on the spillover region rather than on the compound words themselves.

As indicated by the review in the introduction, this finding in English replicates the earlier finding that there is no transparency effect for Finnish compounds (Pollatsek & Hyönä, 2005) and is in line with Underwood *et al.*'s (1990) results for compounds preceded by a neutral context. Although the Pollatsek and Hyönä study used a mix of opaque–opaque and opaque–transparent compounds, the present data suggest that this possible confound was unlikely to compromise their conclusion that there is no transparency effect for lexicalized Finnish compound words.

Why is it that both ours and Pollatsek & Hyönä's reading studies do not show transparency effects whereas two semantic priming studies showed an effect for either OT compounds (Sandra, 1990) or OO compounds (Zwitserlood, 1994), and Libben *et al.*'s (2003) study found effects for OO and TO compounds? One possibility is that the latter studies tap into a (possibly higher order) processing level that could not be captured by the eye-movement measures discussed here. While looking at later processing measures is problematic as the rest of the sentence was not controlled for plausibility (the part of the sentence up to the compound was kept semantically neutral), we did examine whether there were any differences in rereading times for the different compound types in Experiment 1. If opacity only influences later processing, one would expect that (even partially) opaque compounds will be reread more often than their transparent controls. Rereading occurred very infrequently, and no differences were found between the partially opaque, fully opaque and transparent compounds (for all means comparisons, all ps $> .23$), nor between compounds with opaque heads and their transparent controls (all ts < 1). Although eye-fixation measures may be too crude to capture transparency effects, especially on later measures, they have been shown to be able to capture many different and often subtle effects (for an overview, see Rayner, 1998). In particular, semantic anomalies have been shown to lead to early processing difficulty – even on gaze durations on the anomalous word (e.g. Frisson & Pickering, 1999; Rayner, Warren, Juhasz, & Liversedge, 2004). Thus, we think it is unlikely that eye-movement measures would not be sensitive enough to pick up the semantic anomalies that would result for many opaque compounds if the reader combined the constituents' meanings (as presumably happened in Experiment 2). Alternatively, it is also possible that the effects found with semantic priming are at least partially task induced. That is, the number of compound targets in most lexical decision studies examining compounds is proportionally much larger than that in natural language (in Libben *et al.*, 2003, *all* real words were compounds, for example). Thus, it is not improbable that at least some participants quickly came up with an alternative processing strategy. Because we do not have evidence either way, we think that the safest conclusion at this time is that the transparency or opacity of a compound does not exhibit a measurable effect in normal reading.

The lack of a transparency effect found in our reading study is in line with the absence of transparency effects during early visual processing of compounds (e.g. Jarema *et al.*, 1999, Experiment 1; Monsell, 1985) and other complex words (e.g. Rastle *et al.*, 2004). However, semantic transparency effects have been found for derived words when the prime is presented for a longer time (e.g. Longtin *et al.*, 2003; Marslen-Wilson *et al.*, 1994; Rastle *et al.*, 2000), suggesting that there might be different levels of morphological decomposition, for example, a morpho-orthographic and a morpho-semantic level. We think that this might explain some of the inconsistencies in the compound priming studies, though given that we did not find transparency effects in early or late reading measures, it remains to be seen whether morpho-semantic decomposition of compounds happens in normal reading at all. An experiment using biasing preceding contexts (e.g. *Because John likes everything sweet, the honeymoon centred around eating desserts.*) might provide further insights into this issue (see also Underwood *et al.*, 1990). However, it remains an intriguing question why decomposition at the morpho-orthographic level should not have consequences for processing at the morpho-semantic level.

The results are most compatible with the view that, at the morpho-semantic level, the meaning of lexicalized compounds is accessed via the whole-word form. In Experiment 1 if participants had decomposed the opaque compounds, we should have found inflated reading times for these compounds as the semantic integration of their constituents should have been difficult (as was presumably the case when decomposition was forced in Experiment 2). In theory, it is also possible that transparent compounds are processed via the decompositional route and that this fortuitously happens to take the same amount of time as the whole-word lookup for the opaque compounds. While this hypothesis cannot be rejected on the basis of our data, it does not constitute the most parsimonious account of the data. In addition, this account has problems explaining the whole-word frequency effects that are found for compounds (e.g. Bertram & Hyönä, 2003; Pollatsek *et al.*, 2000), though one can still claim that this is restricted to the morpho-orthographic level. Additionally, at least in idiom processing (e.g. Gibbs, 1980; Ortony, Schallert, Reynolds, & Antos, 1978), it has been shown that constructing the literal meaning on the basis of the individual constituents of a phrase takes longer than accessing the stored idiomatic meaning.

Although the findings from the previous eye-tracking studies and the present study are both clear and consistent, they are also puzzling. That is, when readers encounter novel polymorphemic words, they must compose the meanings of the constituents in order to understand them. Moreover, in a language like Finnish, compounding is quite productive so that a typical Finnish reader is likely to see several novel compounds each day. In English, the productivity is probably less and is masked by the fact that novel compounds such as *monkey medicine* would be written with a space. However, novel prefixed words in English such as *unblond* can easily be coined (and probably are frequently coined). Moreover, one's impression is that such novel words are easy to encode and compute the meaning of. Thus, we think that there is an unsolved mystery: if one can easily do this computation for the meaning of novel words, why is it not being done for lexicalized words, or if it is, why are we seeing no evidence of it?

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Appendix: Experimental items

For each item, the (partially) opaque follows the first '/' symbol, with the transparent control word in parentheses. The second '/' symbol delimits the spillover region. The '//' symbols indicate a line break.

Type 1: Opaque–opaque (OO) compounds vs. transparent–transparent (TT1) compounds

(1) John thought the/honeymoon (moonlight)/was extremely/romantic.
(2) Most people believe that John's painful/hamstring (toothache)/distracted/him, causing him to//lose the tennis match.
(3) My neighbour told me that the new/blockbuster (dishwasher)/turned/out to be a huge//disappointment.

(4) When Paulette noticed the accumulation of litter in her/pocketbook (barnyard)/she became//really upset.
(5) Jane always had a/cocktail (cookbook)/on the/counter when she was preparing dinner.
(6) The amount that the/network (farmland)/sold for/was much higher than most people expected.
(7) It was hard to believe that the/jackpot (haystack)/had become/so enormous in such a short//time.
(8) We did not know that the unexpected/deadline (rainfall)/had bothered/Jill so much.
(9) I was told that the/pineapple (honeybee)/sat unnoticed/on the table at the company picnic.
(10) Nobody told me that the/flapjack (paintbrush)/had to/be thrown away, so I left it sitting//there.

Type 2: Opaque–transparent (OT) compounds vs. transparent–transparent (TT2) compounds

(1) The woman next door claimed that my/godchild (snowball)/broke/one of her windows.
(2) The waitress explained that the/buckwheat (gingerbread)/was all/organic and bought from a//local farm.
(3) Sara was surprised to see a/crowbar (nailbrush)/lying/under the kitchen table.
(4) The moment the woman touched the/ragweed (teacup)/a beetle/jumped on her hand.
(5) The comedian joked that the/restroom (songbook)/was so/old it had holes in it.
(6) When the little boy saw the/ladybug (firewood)/he became/all excited and started singing.
(7) When the little girl grabbed the/peanut (pillbox) /her mother/yelled at her to put it//down immediately.
(8) Harriet thought that the/sandalwood (toothpaste)/smelled/so good that she immediately bought//some more.
(9) Keith thought that the/horseradish (meatball)/on his/plate looked pretty old.
(10) John would not acknowledge that his/horseplay (gunshot)/annoyed/the neighbours last night.
(11) Harry told the girl in the cloakroom that his/trenchcoat (raincoat)/was brown/brand-new//and very expensive.
(12) Sammy first noticed the/dragonfly (flowerpot)/when he/woke up from his nap in the hammock.
(13) The woman tried to make sure that the/peppermint (clothesline)/in the/garden would not be//destroyed by the raucous boys.
(14) Janice thought that the/butterfly (rattlesnake)/she saw/yesterday was the biggest she had//ever seen.

Type 3: Transparent–opaque (TO) compounds vs. transparent–transparent (TT3) compounds

(1) Having one's office close to a/chatterbox (lumberyard)/makes/it very difficult to//concentrate.

(2) Tina was annoyed because the/lumberjack (rainstorm)/was so/noisy that she could not meditate.
(3) Samantha complained that her/nightmare (headache)/had caused/her to lose sleep the night//before her job interview.
(4) The inspector announced that the/staircase (woodshed)/had to/be taken down immediately.
(5) As soon as Albert noticed the/litterbug (sandcastle)/he ran/off to tell his mother.
(6) When Martin stepped on the/gingersnap (mousetrap) /his girlfriend/started giggling.
(7) Jay thought that his new/sideburns (hairbrush)/helped/him look a lot better.
(8) The detailed simulation of the/warhead (chessboard)/was an/impressive piece of work.
(9) Jack bought a/doughnut (pocketknife)/from the/corner store with his allowance.
(10) The police were summoned after the/heirloom (mailbag)/had been/reported missing.