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Morphological Parsing by Foveal Split: Evidence from Anaglyphs

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Abstract

We investigated the early moments of visual word recognition, when the retinal information—by hypothesis split vertically along the fovea—is divided into two visual pathways, projecting the right visual field into the left hemisphere (LH), and the left visual field into the right hemisphere (RH). Wearing red/blue anaglyph glasses, participants performed a lexical decision task to compounds (FOOTBALL) and monomorphemic words that were either pseudo-compounds (CARPET) or unsegmentable (JINGLE). The stimuli were presented (masked, 60 ms exposure) in three color combinations: all black, red/blue (ipsilateral visual pathways), and blue/red (contralateral pathways). For the red/blue and blue/red conditions, the colors were split either at the morpheme boundary (legal split) or at a character to the left or to the right of the split (illegal split). We found an advantage (RT and accuracy) of compounds over non-compounds, independent of pathway, and an advantage of legal vs. illegal constituent split. Results suggest that the visual word recognition system performs parsing analyses that are in consonant with the morphological objects of the language. The advantage of pseudo-compounds over unsegmentables suggests that at an early—pre-lexical—stage the system is partially insensitive to the semantic properties of the whole word.

Keywords: visual word recognition; compounds; morphological processing; split fovea theory; anaglyphs

Introduction

What is the role of morphological analysis in the process of visual word recognition? For long this question has been at the forefront of studies on word recognition[1] and language comprehension, more broadly. This is so because decomposing lexical items into their constituent morphemes is key to the productivity of the language system. By hypothesis, lexical productivity is dependent on a rule-based morphological system that takes morphemes, rather than full words, as its basic representations. But whether or not the visual word recognition operates *pari pasu* with a language's morphological system is still an empirical question. Ever since the seminal work by Forster and Taft (Taft & Forster, 1975, 1976; Forster, 1976), most studies have pointed towards a word recognition system that is intrinsically dependent on a morphological analysis that precedes recognition. In Taft and Forster (1975), this process relies on stripping affixes leading to recognition via roots and stems. This suggests that the visual word recognition system is attuned or hard-wired to detect morphemes during the earliest moments of lexical processing.[2] Another important factor in this debate has since been the role of the visual word form area (VWFA; Cohen et al., 2000). This area has been shown to respond to word forms, whether they constitute actual morphemes or whether they include more basic non-word orthographic patterns (Hirshon et al., 2016).

Thus far, the nature of morphological parsing—and whether or not morphological decomposition plays a pivotal role in word recognition—has been investigated with a variety of methods. Most notably, researchers have employed different lexical priming techniques, often combined with other factors and methods (visual masking, sentence contexts, cross-modal presentation, ERPs, eye-tracking) in order to probe the relations that might obtain between morphological constituents and full word forms such as *lifting*/*LIFT*, *govern*/*GOVERNMENT*, *lockable*/ *unlock*/ *UNLOCKABLE* (e.g., Stanners et al., 1979; Marslen-Wilson et al., 1994; de Almeida & Libben, 2005; Pollatsek et al., 2010; see also Forster 1999; and Rastle & Davis, 2008). In visual lexical priming techniques, for instance, the assumption is that responses to a target such as *LIFT*, preceded by a prime such as *LIFTING*, in a lexical decision

[1] Most researchers recognize two temporally distinct stages in lexical processing, an initial "recognition" stage, when word forms make contact with lexical representations, and an "access" stage, when lexical representations are mapped onto meaning—although these terms have often been switched (e.g., Forster, 1979; Foss, 1988). For the most part we deal with "recognition" while also acknowledging that some models postulate a parallelism or a "cascading" effect involving semantic processes in recognition.

[2] By "earliest" moments we refer to orthographical or morphological forms rather than to letter features (e.g., lines) or other lower-level visual features (luminance contrast, texture, color, etc.).

task, should be a function of the morphological relationship between the base *LIFT* and its inflected form *LIFTING*. Many studies employing this kind of technique have shown that word recognition is sensitive to morphological forms, and often to pseudo-morphological strings as well (e.g., *CORNER/CORN*; Longtin et al., 2003; see also Rastle & Davis, 2008, for discussion).

Numerous variables seem to play a role in the prime-target relationships affecting response times, including the extent to which prime and target are morphologically, phonologically, semantically, and orthographically related (Marslen-Wilson et al., 1994; Rastle et al. 2004). Recent studies have suggested that word recognition and lexical access processes are "cascading", involving multiple, interacting factors, including how much semantic information about a word's constituents affect early processes of recognition (Davis et al., 2019). Yet, it remains to be determined the degree to which the visual word recognition system reacts to pure morphological *forms*—including pseudo-morphemes—regardless of their status as lexical constituents.

Compounds—roughly, words that are constituted by the combination of other free morphemes, such as *FOOTBALL*—constitute perhaps the clearest testing ground for the mechanism of morphological decomposition (Libben, 2014). This is so for several reasons. First, compounding is the most productive lexical process, with novel words pertaining to all syntactic classes being constantly created (e.g., *WEBSITE*, *SNAPCHAT*). Second, English lexical compounds are usually formed by the combination of two free roots; and whether or not compounds are decomposed during word recognition requires investigating a process that relies on the relationship between the head of the compound (e.g., *BALL*) and the modifier (e.g., *FOOT*), as well as how each constituent might contribute information to the meaning of the whole word. Thus, compounding constitutes the paramount case of *compositionality*—when the meaning of a whole expression is a function of the meaning of the parts and how they are structured together. Compositionality is taken to be a feature of human cognitive architecture and key to linguistic and conceptual productivity (Fodor & Pylyshyn, 1988). Third, for the vast majority of English lexical compounds, the left-most constituent (e.g., *BALL*) is the *head* and carries most semantic and syntactic properties of the whole compound. Whether or not morphological structure plays a role in compound recognition, can be tested by modulating readers' exposure to the head of the compound (de Almeida & Libben, 2002) in order to determine its contribution to the word's meaning.

We sought to investigate morphological processing by exploiting the nature of retinal projections in early visual processing. Several studies have shown that the retina is split vertically along the fovea, distributing the retinotopic information along two visual pathways, projecting the right visual field into the left hemisphere (LH), and the left visual field into the right hemisphere (RH) (e.g., Brysbaert et al., 2012). While contralateral (nasal) projections are taken to be stronger than ipsilateral (temporal) ones (Obregon & Shillcock, 2012) for word recognition, compounds provide for an opportunity to understand how these early retinal projections interact with posterior representations involved in word identification (e.g., VWFA; Cohen et al., 2000). Thus, binocular fixation on the morpheme boundary of a bimorphemic compound should yield the following projections: the compound head (e.g., *BALL*), carrying most syntactic and semantic information, is projected to the language dominant LH, while the modifier (e.g., *FOOT*) is projected to the RH. Notice that it is estimated that interhemispheric transfer of information oscillates between 12 and 25 milliseconds (Brown et al., 1998; Cohen et al., 2000), which would yield an advantage for the head during the early stages of word recognition and semantic composition.

What motivated our investigation, in particular, was that these neuroanatomical distinctions allowed us to explore the differences in response time (RT) and accuracy to a compound by ensuring that its segments (either full constituents or partial constituents) are being processed independently. In other words, by anatomically separating which segments of a word make the initial contact with the lexicon we could gain insights into the earliest moments of word recognition—with RTs and accuracy potentially reflecting the nature of the initial contact between stimulus and stored representations. In the case of compounds, for instance, this can be determined by contrasting word and non-word segments obtained from the point of fixation. For instance, presenting *FOOT* to the RH and *BALL* to the LH can give the compound a "head-start" because the full head is making the initial contact with stored representations before the full word is composed. But it is not clear what happens if the different hemispheres get non-word segments such as *FOO* and *TBALL*. Under both splitting conditions—morphologically legal and illegal splits—the two segments are fused yielding the same *FOOTBALL* representation. However, an advantage of legal over illegal split can inform us about two important issues in visual word recognition: (a) the nature of codes that initially make contact with lexical representations—whether they are *morphemes* or orthographic sequences; and (b) the nature of morphological analyses in word recognition: whether they occur before the initial contact between stimulus word and stored representations, or whether these analyses occur after the full word has been recognized.

We manipulated compound recognition using a novel lexical decision with masked presentation technique, involving words colored in blue and red (or in black, as baseline) while subjects wore red/blue anaglyph glasses. The novelty of our manipulation includes two main lexical factors: (1) word type, contrasting (a) compounds (*FOOTBALL*, *BLACKBIRD*), (b) monomorphemic pseudo-compounds (those monomorphemic words that could potentially constitute compounds; e.g., *CARPET*, *SHAMROCK*), and (c) unsegmentable monomorphemic words (*VACCINE*, *JINGLE*); and (2) legality of constituents or non-constituents of these words. For this manipulation we induced the splitting of the word segments along morpheme boundaries (*FOOT+BALL*), pseudo-morpheme boundaries (*SHAM+ROCK*), or non-morpheme boundaries (*JIN+GLE*), or by inducing the splitting along non-morpheme/pseudo-morpheme boundaries for compounds (*FOO+TBALL*) or pseudo-compounds (*SHA+MROCK*). This legal/illegal split was obtained by coloring the segments such that they would be filtered out by the corresponding lens of the anaglyph glasses, or by simply presenting the words in black with the morpheme boundary—or the illegal split point—corresponding to the center of fixation. This manipulation allowed us also to investigate yet a third factor: (3) the relative contribution of visual pathways to early word recognition. Using a haploscope, Obregon and Shillcock (2012) obtained a higher degree of accuracy for letters presented via contralateral pathways in contrast to ipsilateral pathways. While their goal was to understand the relative strength of the visual pathways using a psychophysical method, their materials were restricted to four-letter monomorphemic words. Our manipulation allows for the independent separation of visual pathways by coloring word segments (morphemes or not) to be projected onto different sides of the two retinas independently (see Fig. 1)

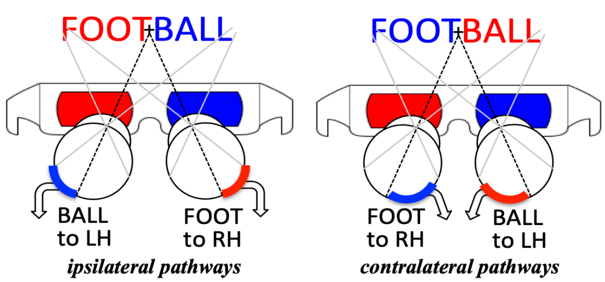


Figure 1: An illustration of one of our main manipulations with legally split morphemes projecting the two visual fields (the two morphemes of the compound) contralaterally via ipsilateral (temporal) pathways or contralateral (nasal) pathways. The "+" represents the fixation point which in our procedure antecedes the presentation of the target. See text for other experimental conditions.

In our task—which involves masked, brief (60 ms) presentation of stimuli like in Fig.1—subjects simply make a lexical decision (word/nonword). A potential advantage of our method over priming techniques is that it does not require manipulating prime-target relationships, which are difficult to control due to factors such as prime-control frequency, morphological family size, length, *n*-gram frequency, etc. (see, e.g., Amenta & Crepaldi, 2012). Moreover, the advantage of this technique over simple (i.e., unmasked) or masked lexical decision tasks is that, by controlling the exposure to different word segments and pathways, we can measure the relative contribution of these different segments—morphemes or not—to RTs and recognition accuracy. While in both conditions, as seen in Fig. 1, the compound head is projected directly onto the LH, the head has an advantage over the modifier for its supposedly direct access to the VWFA in the language-dominant hemisphere. In terms of processing time, this advantage has been estimated to be as little as 12 ms (Brown et al., 1998; Cohen et al., 2000). However, when the segments are illegally split, this advantage should disappear, requiring full composition for a lexical decision to be made.

We thus made three main sets of predictions about RTs and accuracy for the three kinds of stimuli we employed (we will refer to faster RTs and higher accuracy as an "advantage" of one stimulus type over another). First, we predicted an advantage of legally split compounds over illegally split ones if compounds are recognized by their constituent morphemes. Second, if the early visual word recognition system relies on a non-semantic, morpho-orthographic procedure for breaking constituents, a similar "legality" effect should be obtained with pseudo-compounds that are legally split (e.g., *SHAM+ROCK*) compared to those that are illegally split (*SHA+MROCK*). And third, based on Obregon and Shillcock's (2002) results, we predicted an advantage of contralateral pathways over ipsilateral pathways. Although this third general prediction in principle bears no direct relation to the mechanisms of lexical processing—whether or not morphological constituents are detected during recognition—factors such as fixation disparity, the flexibility of vengeance and its consequent reading span variability (see, e.g., Shillcock et al., 2010) may affect the nature of information picked up by the different hemiretinas and how they are projected into the VWFA and other language areas.

Method

Participants

Fifty-four individuals (36 females) participated in this experiment. They ranged in age from 19 to 77 years ($M = 27$; $SD = 12$). All participants had normal or corrected-to-normal vision and were native speakers of English.

Materials and Design

Materials consisted of 168 words ranging from six to ten characters in length, of the following types: (1) adjective-noun and noun-noun compounds (*FOOTBALL*) , (2) pseudo-compounds (monomorphemic words that consist of two adjacent letter strings which could each be a well formed word of English (*SHAMROCK*), and (3) unsegmentable monomorphemic words (words with no constituent letter strings that form words of English; *JINGLE*). Target words were matched for mean length, whole word lexical frequency, mean constituent length, and constituent frequency (compounds and pseudo-compounds only). Additionally, three types of non-words were created: (1) nonword-nonword "compounds" (*GRIENLORP*), word-nonword "compounds" (*TREESNIZE*) and nonword-word "compounds" (*FLURKBOUNCE*). These stimuli were created to ensure that successful lexical decision required processing the entire word, not just the left or right constituent. The experiment comprised three independent variables: word type (compound, pseudo-compound, and unsegmentable words), word splitting pattern (legal, illegal), and visual pathways (both, ipsilateral, and contralateral), as in Fig.1.

Apparatus and Procedure

The experiment was presented using an Apple Mac computer running OS 9.2 attached to a 21" CRT monitor (100Hz, 10ms screen refresh rate). Stimuli were presented through Psyscope 1.2.5 software (Cohen et al., 1993) in a randomized order. Target items were presented either in black or in a combination of blue and red font against a white background. All words were displayed centered on the screen and ranged between six and ten characters. All letters were uppercase, typed in monospaced Courier font and extended between 6 and 8 degrees of visual arc. Participants were seated 51 cm away from the monitor with their heads stabilized by a chin and forehead rest to ensure that their gaze focused on the center of the screen. During the experiment, participants wore NeuroTracker anaglyph glasses as they performed a lexical decision task. The left lens of the glasses was red and the right lens, blue. The different letter string constituents, determined by the splitting condition, were filtered through the glasses so that any letters typed in blue (RGB 0-1-1) would only go through the red lens, letters typed in red (RGB -1-0-0) only passed through the blue lens and black font stimuli (RGB -0-0-0) passed through both lenses. Participants' RTs were recorded by a CMU response box with two main buttons: a green button on the right corresponding to the "yes" answer and a red button on the left corresponding to the "no" answer.

The experiment included eight practice trials and 280 experimental trials. Each trial began with a 1000ms fixation cross at the center of the screen, followed by the target item, appearing for 60ms. Then, a backward mask made up of a series of twelve 'X's in black 48pt Courier font in capital letters appeared on the screen for 500ms. Subjects were instructed to make a lexical decision as soon as the word/nonword flashed on the screen. The full session lasted about 20 minutes.

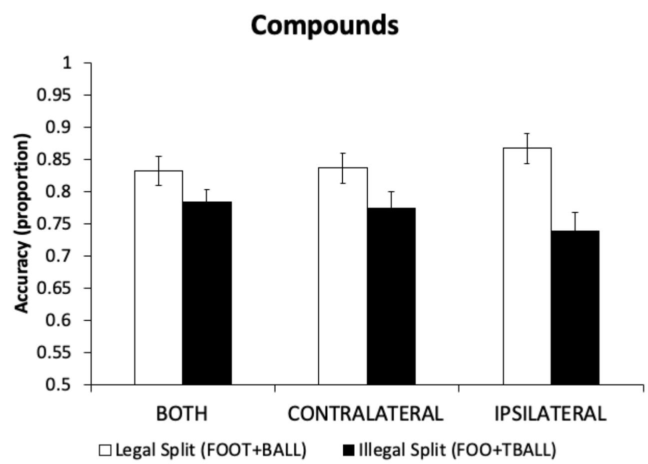
Results

Prior to conducting the analyses, participants' overall accuracy to the lexical decision task was screened. A total of six participants scored below chance (i.e., below 50%) and were thus removed from all analyses. Further, response latencies below 200 ms and greater than 1200 ms (4.52 % of responses) were removed. Subsequently, participants' responses that were 2 standard deviations above or below their respective means (5.07 % of responses) were replaced by their upper or lower standard deviation cut-off tail values.

In order to determine whether participants' accuracy and response times (RTs) were affected by split type, word type, and pathways, we conducted linear mixed effects (LME) models (Baayen et al., 2008) using the lme4 package (Bates et al., 2011) for the R statistical programming environment (R Dev. Core Team, 2011). For all LME analyses, the models were fitted using a backwards step-wise elimination procedure, whereby the predictor variables that did not significantly improve the model as indicated by likelihood ratio testing were subsequently removed (Winter, 2013). The models analyzed the effects of three independent variables: split type (legal, illegal), word type (compound, pseudo-compound, unsegmentable), and pathways (ipsilateral, contralateral, both pathways) on the dependent variables: RTs and accuracy. Split type, word type, and pathways were entered as fixed effects. The model for the analysis of RTs had random intercepts for subjects and items, and the analysis of accuracy had random intercepts for subjects and items as well as by-item random slopes for the effect of word type, as justified by the likelihood tests. The *p*-values were derived for each predictor variable by comparing the fitted model to a minimally contrasting null model that excluded the relevant term. Planned comparisons were conducted using the emmeans package (Lenth et al., 2018).

Response Times

Only correct responses to the lexical decisions were included in the model. The full model was compared to a null



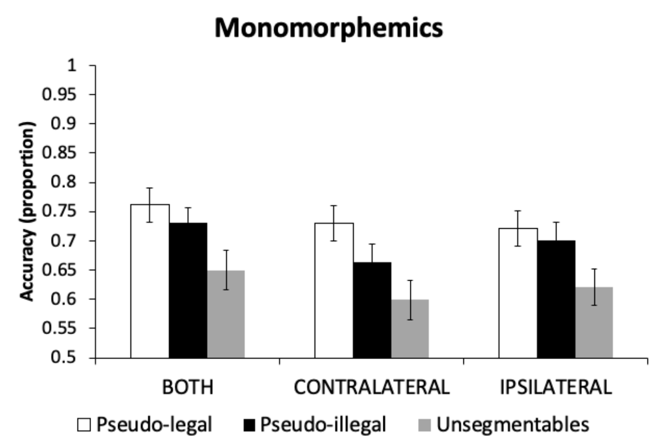


Figure 2: Mean response accuracy for compounds and monomorphemics as function of split type (legal v. illegal) and visual pathway. Error bars are standard errors of the mean.

model consisting of only random predictors and was found to provide a statistically significant better fit to the data, ($\chi^2(14) = 108.76$, $p < 0.001$). There was a main effect of split type ($\chi^2(6) = 14.23$, $p = 0.027$), a main effect of word type ($\chi^2(9) = 62.44$, $p < 0.001$), and a main effect of pathway ($\chi^2(10) = 37.73$, $p < 0.001$). There was also a statistically significant interaction between split type and word type ($\chi^2(12) = 84.56$, $p < 0.001$), split type and pathway ($\chi^2(12) = 43.33$, $p < 0.001$), and word type and pathway ($\chi^2(13) = 93.55$, $p < 0.001$), but there was no significant three-way interaction ($\chi^2(9) = 12.868$, $p = 0.17$).

Legality and Word Type Planned comparisons, using Tukey's correction, revealed that participants RTs were significantly faster when they were presented with legally split words, as opposed to illegally split words ($p = 0.039$, $d = 2.05$), irrespective of word type and pathway. Results also showed that compounds were significantly faster than pseudo-compounds ($p < 0.001$, $d = -6.46$) and unsegmentables ($p < 0.001$, $d = -6.90$). However, there was no difference in RTs between pseudo-compounds and unsegmentables ($p = 0.14$, $d = -1.90$). Also, participants responded significantly faster to legally- than to illegally-split compounds ($p = 0.007$, $d = -2.70$), as well as legally-split pseudo-compounds ($p < 0.001$, $d = -2.40$). But there was no legality effect for pseudo-compounds ($p=0.45$, $d = -0.75$).

Legality, Word Type, and Pathways Results showed that words presented simultaneously to both pathways engendered significantly faster RTs than words presented to the contralateral ($p < 0.001$, $d = -3.72$), or ipsilateral ($p < 0.001$, $d = -5.25$) pathways. There was no difference between contralateral and ipsilateral pathways ($p = 0.29$, $d = -1.51$). There was also no difference in RTs between legally- and illegally-split compounds presented to both pathways simultaneously ($p = 0.46$, $d = -1.81$), nor was there a difference between legally- and illegally-split compounds presented to contralateral pathways (p = 0.99, $d = 0.29$). However, when compounds are presented to ipsilateral pathways, legally split compounds are faster than illegally-split compounds ($p = 0.02$, $d = -3.17$). Also, legally-split compounds presented to both pathways were marginally faster than legally-split compounds presented to contralateral pathways ($p = 0.069$, $d = -2.74$), but there was no difference between both pathways simultaneously and ipsilateral pathways ($p = 0.42$, $d = -1.88$) for legally split compounds. There was also no difference in RTs between legal compounds presented to ipsilateral pathways and legal compounds presented to contralateral pathways ($p = 0.95$, $d = 0.89$).

Accuracy

The full model was compared to a null model consisting of only random predictors and was found to provide a statistically significant better fit to the data, $\chi^2(19) = 533.37$, $p < 0.001$. Results also showed a main effect of split type ($\chi^2(6) = 44.74$, $p < 0.001$), a main effect of word type ($\chi^2(9) = 37.55$, $p < 0.001$), and a marginally significant main effect of pathway ($\chi^2(10) = 17.02$, $p = 0.074$). There was also a statistically significant interaction between split type and word type ($\chi^2(12) = 75.09$, $p < 0.001$), split type and pathway ($\chi^2(12) = 53.72$, $p < 0.001$), word type and pathway ($\chi^2(13) = 45.41$, $p < 0.001$), as well as a significant three-way interaction ($\chi^2(9) = 17.20$, $p = 0.046$).

Legality and Word Type Figure 2 shows mean accuracy across all conditions. Planned comparisons revealed that participants were more accurate when the words were legally split ($p < 0.0001$), regardless of word type and pathway. Results also showed that participants were significantly more accurate when responding to compounds than pseudo-compounds ($p < 0.0001$), and unsegmentables ($p < 0.0001$). Also, legally split compounds engendered greater accuracy than illegally compounds ($p < 0.0001$), and legally split pseudo-compounds ($p < 0.0001$). For pseudo-compounds, there was also an effect of legality ($p = 0.02$).

Legality, Word Type, and Pathways There was no difference in accuracy between words presented to the different pathways: no difference in accuracy between words presented to both pathways and contralateral pathways ($p = 0.12$), between both pathways and ipsilateral pathways ($p = 0.58$), and between contralateral and ipsilateral pathways ($p = 0.72$). There was also no difference in accuracy between legally- and illegally-split compounds presented to both pathways ($p = 0.42$), and between legally- and illegally-split compounds presented to contralateral pathways ($p = 0.12$). However, responses to legally-split compounds were significantly more accurate than to illegally-split compounds when presented to the ipsilateral pathways ($p < 0.0001$).

Discussion

We investigated the role of morphological parsing in word recognition by contrasting compounds, pseudo-compounds, and monomorphemic words in a lexical decision task involving anaglyphs. Our manipulation allowed us to contrast the perception of morphological constituents with non-constituent letter segments. In addition, we were able to evaluate the relative contribution of each visual pathway to word recognition. Our main finding was an effect of legality—with legally-split compounds engendering faster and more accurate responses than illegally-split compounds. For pseudo-compounds, our results show an effect of legality only for accuracy but not RT. Taken together these results point to a word-recognition system that may operate at two intersecting levels of analysis, with an initial form-only parse that may be influenced by the content of the whole word only at a later stage. This may account for the difference in accuracy between pseudo- and true compounds: at an early, semantic insensitive morphological parsing stage, both *FOOT+BALL* and *SHAM+ROCK* are segmented for analysis, with only *FOOTBALL* benefiting from semantic composition, thus leading to faster and more accurate responses during lexical decision. Our suggestion is that, although both *FOOT+BALL* and *SHAM+ROCK* are initially evaluated as complex, *SHAM+ROCK* fails when a morphological analysis yields the 'head-modifier' structure for interpretation.

We see our study as providing a unique type of evidence for a pre-lexical morphological parsing. The hypothesis of a "pre-lexical" analysis stems from the idea that the word recognition system stores primarily free morphemes together with rules for computing inflectional, derivational, and compounding representations. Our two main manipulations—word type and split legality—support the view that the parser operates at the entry level breaking constituents for recognition and further analyses. As the accuracy data show, there is a legally split advantage over illegally split compounds. In this case, the earlier arrival of *BALL* may act as opening the lexicon to that word/constituent, which is then composed with the modifier *FOOT*, and thus arrives slightly later via interhemispheric transfer. We reasoned that if the full word *FOOTBALL* were to be analyzed after its full recognition, a constituent such as *BALL* would have no advantage over an illegally-split segment such as *TBALL*. More importantly, this finding extends to pseudo-compounds, suggesting that this morphological parser is semantically insensitive in its initial analyses of the incoming stimuli.

We should, however, consider two other interpretations for our pattern of results. One is that the differences between compounds and pseudo-compounds are driven by stimulus factors such as morphological family size: there may be more compounds whose head is *BALL*, than compounds with *ROCK*. In other words, the productivity of *BALL* enhances the likelihood that the full word is a true compound. We have not yet entered this factor into our analyses. The second is that our pseudo-compounds were not controlled for semantic plausibility: that *SHAMROCK* is not likely to be a kind of rock modified by 'sham'. These analyses will also constitute future directions of the present study.

Regarding visual pathways involved in word recognition, our results are at odds with those obtained by Obregon and Shillcock (2002). We found a small advantage of ipsilateral pathways over contralateral ones in the processing of legally-split compounds, but no differences between the two pathways for other word and split types. One possible interpretation for these conflicting results may be in the nature of the stimuli both studies employed.

Our technique allows for the possibility of further investigating the relative contribution of foveal split and different pathways to word recognition using purely psychophysical measures. Despite the differences between our results and those of Obregon and Shillcock, we concur with them that research on reading and visual word recognition should not neglect neuroanatomical variables which may play an important role in early reading. Methodologically, we also agree that, given the difficulties of investigating the nature of the fovea and its cortical connections in natural reading and visual word recognition, neuroanatomical variables can be investigated relying on new psychophysical techniques such as the one they developed and the one we developed in the present study.

More broadly, we have shown that by employing anaglyphs and coloring different word constituents, thus controlling for the nature of the input provided to each hemisphere and pathway, we can further understand the nature of morphological analysis at its earliest moments. The technique we have developed has allowed us provide further evidence for the existence of an early—semantic insensitive—pre-lexical morphological parser deployed in word recognition.

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