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Lexical composition and the production of compounds: Evidence from errors in naming

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Whether the production of a morphologically complex word recruits compositional procedures appears to depend on the properties of the particular word-formation process at hand. Since the types of word formation that appear to enlist composition include regular inflection and productive derivation, an argument can be made for the role of morphological productivity in determining the approach taken to lexical production. However, morphological productivity typically entails semantic compositionality, so it could be that compositional procedures are exploited only when the meaning of the complex word is exhaustively characterised in terms of the meanings of its immediate morphological constituents. It is argued here that the lexical production system takes a compositional approach to processing morphologically complex forms in cases of productive word formation even if the semantics of the word cannot be derived formally from the meaning of its constituents. Evidence is presented from a case of acquired naming impairment in a patient whose ability to name objects with compound names is particularly disrupted.

INTRODUCTION

Many of the central issues in the theory of lexical processing pertain to how morphological structure determines the way in which a word is

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recognised, stored, or produced. Principal among these issues is the question of whether the composite nature of a word form is reflected directly in the procedures for recognising or producing it. If a word is morphologically complex, does this mean that recognition requires decomposition and production requires composition? One could imagine that the results which appear to reflect a compositional approach derive instead from how the processes of identification or generation are affected by the manner in which a form is stored (e.g., from the associative structure of a lexicon of whole-word representations that is organised by morphological and/or semantic relation—e.g., Segui & Zubizarreta, 1985), or by the type of information that is included in the stored representation. For example, we may take the null hypothesis to be that morphologically complex words are stored and retrieved as whole-word representations, and that these representations encode the phonological, but not morphological, properties of the lexical items in question. An elaborated version of this whole-word approach might augment the stored form with a representation of its morphological constituent structure and other pertinent information regarding its morphology. In practice it is often difficult to distinguish evidence for models in which composition is incorporated directly into the procedures for lexical comprehension or production from evidence for processing models with such morphologically enhanced whole-word representations. Hence, it is of some interest when new data can be brought to bear on this issue.

The task of identifying such data is complicated by the fact that the approach that the lexical processing system takes to storing or producing a morphologically complex word can depend on the properties of the specific word-formation rule at hand. For example, when we asked whether the forms **walked** and **natural** are produced by combining a stored base form with a suffix (as opposed to using whole-word retrieval mechanisms), the answer appears to be tied, in some way at least, to the productivity of the affixes. Here productivity means the extent to which a word formation rule can be used to form new words freely (Baayen & Lieber, 1991). For example, the morphology of the regular past tense in English is fully productive, and there is evidence that compositional mechanisms are invoked in the production of such forms from speech error data (Garrett, 1980, 1982), acquired language impairments (Badecker & Caramazza, 1991; Badecker, Hillis, & Caramazza, 1990; Badecker, Rapp, & Caramazza, 1996), and normal psycholinguistic and acquisition studies (Clahsen, Rothweiler, Woest, & Marcus, 1992; Marcus, Brinkmann, Clahsen, Wiese, Woest, & Pinker, 1995; Prasada & Pinker, 1993; though see Bybee, 1995). Productive derivation (as exemplified in **darkness**, **cloudless**, and **definable**) has also been argued to be processed using compositional mechanisms, while non-productive derivation (as exemplified by **natural**) has been observed to elicit performance indicative of whole-word retrieval in orthographic and phonological output (Badecker & Caramazza, 1991; Badecker et al., 1990).

To what degree, though, is the approach to lexical production determined by the productivity of the morphology involved? As Aronoff (1976) and others have pointed out, the productivity of a word-formation process correlates with two properties of morphologically complex words: the semantic compositionality and the phonological transparency of the derived form. For example, affixation leaves the stem unchanged when **-ness** is suffixed to an adjective, but there are a variety of stem modifications that result from the suffixation of non-productive suffixes like **-al**, **-ic**, **-ity**, and **-ous**. Similarly, the semantic content of an inflected form like **walked**, or of a productively derived form such as **darkness**, is fully predictable from the meanings of the component morphemes; whereas the meaning of a form like **natural** is not similarity transparent. The performance question, then, is whether the apparent role of productivity in determining the processing approach taken with any subset of the lexicon can be accounted for in terms of these correlated properties of the morphologically complex forms. Is the productivity of a rule alone sufficient to determine whether the lexical output system will employ compositional versus whole-word retrieval mechanisms? Or must the output of a compositional procedure always be both phonologically transparent and semantically predictable with respect to the form and meaning of the morphological input?

Compounding is one type of word-formation that can help to cleave semantic predictability from other factors that might determine whether a word is produced using either whole-word retrieval mechanisms or procedures for formal composition. By any criteria, the grammatical device of compounding is fully productive in English. Nevertheless, the meaning of certain compounds, in particular root compounds, is generally not predictable from the meaning of the constituent parts. In most cases of English compounding, the meaning-to-form relation is not entirely arbitrary (e.g., the meanings for **clothes** and for **pin** are not wholly unrelated to the meaning of **clothespin**), but the relation is typically idiosyncratic in the sense that it is not determined by the content of the word formation process. For example, there is an intuitively clear sense in which compounds such as **horse pill** may be thought of as semantically composite, but the manner in which the complex meaning of this form relates to the meanings of **horse** and **pill** does not provide a ready guide for interpreting other compounds (e.g., **horse latitude** or **horse jump**). Compounds may differ from one another in terms of the WAY in which their whole-word meaning relates to the meanings of their constituent words (compare **fertility pill**, **nausea pill**, **garlic pill**, and **horse pill**) and also in the EXTENT to which these meanings are related (compare **butterfly**, **buttercup**, **butterball**, **butter dish**). How do these idiosyncrasies affect the approach taken by the lexical system to storage or production? Given that compounding is an extremely productive word-formation process (in English), evidence concerning how root compounds are stored or produced can provide important insight into the extent to which semantic predictability plays a role in determining how the lexical system operates.

MECHANISMS OF COMPOUND PRODUCTION

On any account of lexical processing, the production model must accommodate the conventional nature of compounds like **butterfly** and **buttercup**. Hence, in a model that posits independent entries for familiar words with idiosyncratic meanings, a separate stored representation will be required for each such lexical item. This requirement applies even in cases where there is a clear relation between the meaning of a compound's constituents and the meaning of the compound as a whole (e.g., **lighthouse**). The fact that the principles we employ for interpreting novel compounds would easily admit the interpretation that a **lighthouse** is a house where lights are manufactured, sold, repaired, polished, or exhibited, or the fact that the kind of structure dubbed **lighthouse** could just as easily have been labelled **marine light**, **shoal beacon**, **beacon tower**, or any of a myriad of other compound appellations means that there must be separate entries for the less opaque compounds as well. However, the mechanisms for producing these words may involve multiple levels of lexical representation, and the issue of whether an item-specific processing unit is employed in production comes up at each of these levels. For example, within the framework of lexical production that distinguishes *lemmas*, modality-neutral lexical representations, from *lexemes*, modality-specific representations of lexical form (see Dell, 1986; Garrett, 1982; Levelt, 1989), the retrieval of lexical forms may occasion a compositional process despite the involvement of item-specific lemmas for conventional compounds. For the sake of exposition, we will contrast compositional and whole-word approaches within this two-level model of production. (A fuller discussion of the lemma/lexeme distinction appears in the general discussion section of this paper.)

On a pure whole-word model of compound production, the stored representation of a target form is called up as a single lexical item. For example, on such an account the stored lexical form for the mono-morphemic word **butter** is functionally independent from the homophonous constituent of the compound **butterfly**, so when a speaker produces the compound, the stored form of the mono-morphemic word is not engaged. While this production model does not exploit compositional

Lemma for 'paw'

semantics:	foot of canine or feline animal
Noun, +count, ...	
form:	go to address 235

Lemma for 'south paw';

semantics:	left-handed pitcher
Noun, +count, ...	
form:	go to address 101

Figure 1. Example lemmas for mono-morphemic words and compounds on the whole-word retrieval account of compound production.

procedures in the production of compounds, the account does not entail that morphological structure has no role to play in the production process. Depending on one's theory of the lexicon, an item that is accessed using whole-word based retrieval mechanisms may nevertheless have internal structure of one sort or another (such as a specification of the word's prosodic and/or morphological constituents), and these features of the stored representation could be exploited by the production system in some way or another. Nonetheless, the internal structure of the retrieved representation does not, by hypothesis, come into play in the retrieval process. In other words, the question of whether compound retrieval is accomplished by addressing a single entry in a lexicon of forms may be answered separately from the question of what kind of internal structure this stored representation may have. It is this feature of the whole-word model that is illustrated in Figure 1.

Consider, now, a model of lexical production in which the internal structure of a compound is directly reflected in the retrieval process. On such a compositional account, there are three processes that are invoked in the normal case of compound retrieval:

a. retrieving (or constructing) a structural representation (e.g., $[_N N_1 N_2]$);
b. retrieving lexical forms (lexemes) corresponding to each of the components of the compound; and
c. linking (or associating) each of the retrieved lexemes with specific positions in the structural representation.

In the vocabulary of the two-stage model of lexical production, we may contrast an addressing procedure made up of these three operations with

Lemma for 'paw'

semantics:	foot of canine or feline animal
Noun, +count, ...	
form:	go to address 235

Lemma for 'south paw;

semantics:	left-handed pitcher
...	
form:	Form 1: go to address 386 Form 2: go to address 235 In [X H], Form 1 = X; Form 2 = H

Figure 2. Example lemmas for mono-morphemic words and compounds on the compositional account of compound production.

the simple addressing procedure invoked for mono-morphemic forms as indicated in Figure 2. Note that this procedure should not be regarded as "rule governed" in the sense that a compositional procedure for generating regularly inflected forms might be, but rather as a process that is initiated by a complex pointer in the lemma for the compound. In other words, this would be an item-initiated procedure, as in Stemberger's (1985) "minor rules".

One indication that this compositional account of compound production is correct is that there are instances of naturally occurring speech errors in which the constituents of compounds are misordered. For example, Stemberger (1985) cites the compound error in (1); and the error corpus in Fromkin (1973) includes compound-internal exchange errors like those in (2) and exchange errors between a compound constituent and a non-constituent like those in (3).

(1) a. Did we miss the [trail [turn-off]]?
$>^e$ ... the turn trail-off?
b. Can you push the [ash tray] over here?
$>^e$ ... Can you ash the push tray over here?

(2) a. in her [[paper doll] box]
$>^e$ in her doll paper box
b. I have to replace my [projector bulb]
$>^e$ ... my bulb projector

(3) a. a fifty-pound bag of [dog food]
$>^e$ a fifty pound dog of bag food

b. the unique feature of [factor analysis]
$>^e$ the unique factor of feature analysis

Misorderings like these bear the classical signs of exchange errors that arise in the construction of Positional Level representations (Garrett, 1980, 1982): They are phrase internal, and the interchange may involve items that differ in grammatical category (e.g., the compound-internal exchange of *trail* and *turn* in (1a), and the exchange of the compound-external verb *push* and the compound-internal noun *ash* in (1b)).[1] More importantly, these errors are not expected if the compound is retrieved as a single, whole-word representation. Hence, the misordering errors provide some support for the notion that the lexemes for compound constituents are independently retrieved and fit into the Positional Level frame.

The whole-word retrieval and compositional approaches to compound production also make somewhat different predictions concerning how the production process might go awry in cases of acquired naming deficits. The assumption that both accounts share is that the selection and retrieval processes are subject to interference from lexical competitors at their respective levels (i.e., the lemma and lexemic levels), and that interference from these competitors can result in substitutions of semantically and/or phonologically related forms. Where the two theories of compound production differ is in how the substitution should be manifested. For example, failure to retrieve a stored whole-word representation may occur because another lexical item competes with the target form (through some activation process), and this competitor wins out; or because the retrieval process only results in a partial specification of the target. In the former case, one might expect that the substitutions will result in the production of other stored word forms (e.g., the hypothetical error **cowboy** → *wagon*) which compete with the target based on semantic relatedness or formal similarity. In the latter situation, one might suppose that the output system could fill in some (lexical or non-lexical) material for what remains unspecified in the retrieved representation. On the version of the whole-word based model that does not encode the target's morphological

[1] It should be noted, though, that most of the attested examples of compound constituent exchanges which violate the category constraint do appear to be subject to another, lexicon internal constraint: The forms which take part in exchanges of different category have morphologically related forms that are of the target category. That is, *turn* in the endocentric nominal compound *turn-off* is a verb, but there is a related noun *turn* (as in *take the next turn on your left*). Ferreira and Humphreys (1999) induced word exchanges experimentally and found evidence based on a shift in stress that the related lexical entry is indeed implicated in category-changing local exchanges (e.g., *recórd the tape* → *tape the récord*).

structure in the lexemic representations, this filling-in process could not differ for mono-morphemic and compound targets. So, if the missing parts of a partially specified form can be ‘filled in’ with lexical items that are competing with the entire target, then such substitutions should be observed without regard to the morphological status of the unspecified portion of the target. Such a distinction might be made, though, if the stored phonological representation for a compound includes a specification of its morphological constituent structure. In this case, though, the lexical forms that we would expect to intrude are those which compete with the target form in its entirety (since retrieval is, by hypothesis, whole-word based). In other words, we would expect that a form-based partial substitution will not involve ‘filling in’ lexical items that are related only to one or the other of the constituents of the target compound.

Contrast this with the different consequences of a compositional approach. Assuming that the structure itself has been appropriately specified, there are two ways in which the hypothesised compositional process may fail: (1) by failing to retrieve one or both of the lexical components that make up the compound, and (2) by associating a retrieved item with the wrong structural position. We should further expect that failure to retrieve a lexical component may be manifest either in an omission of that constituent of the compound, or in a substitution for that constituent. That is, substitutions may occur for either or both of the constituents of the target compound. Finally, one would anticipate that the relationship between the compound target and the intruding element in substitution errors will differ according to the substitution type (i.e., in semantic vs. form-based substitutions). Since lemma selection for a compound accesses a single representational unit, substitutions based on semantic relatedness should involve substituting elements that are associated with the compound as a whole (as opposed to being related in meaning solely to one or the other of the compound’s constituents).[2] On the other hand, if a substitution is form-based, then one would anticipate that the substituted constituent of the target compound will be replaced by a word form that is phonologically related to one or the other of the

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[2] Semantic paraphasias do not entail a semantic processing deficit, and can arise instead from a processing break-down at a post-semantic level – i.e., from an impairment that renders a phonological form inaccessible (Caramazza & Hillis, 1990). If lexical competitors at a semantic level send enough activation to their corresponding form-level representations, then a failure to access the target lexeme could allow one of these other forms to reach activation threshold. By this means, a form level deficit can give rise to semantic paraphasias. Since the semantically related form will be related to the whole target, though, this means that the form that substitutes for one of the two lexemes for a compound should be related to the whole of the compound (because it is a semantic neighbour of the compound’s lemma that activates the intruding lexeme on this account).

compound components (as opposed to being related in form to the entire target compound). These restrictions on the relationship between a target compound and substituting elements stand in contrast to the expectations generated for substitution errors in the whole-word based processing model. If the target form for a compound were retrieved on the basis of a whole-word procedure, then either constituent substitutions should not occur at all (if the morphology of the target is not encoded in the stored representation of form), or the relation manifested in the substitutions should be rooted in the formal properties of the whole target form rather than the formal properties of the constituent parts.

To recapitulate, the two approaches to compound production can be summarised as in Figures 1 and 2.[3] On the retrieval approach (Figure 1), the link from the lemma level representation to a stored lexical form will not distinguish compound and mono-morphemic words. If there are indeed differences regarding their morphological structure, they must be differences between the two types of forms that are retrieved. (That is, the issue of whether such distinctions are made within the storehouse of forms is independent of the retrieval mechanisms involved.) On the compositional approach, though, the two types of words are distinguished in terms of how their forms are retrieved (Figure 2). In particular, the procedure for getting the form of compound words involves constructing the target form out of the two stored lexical forms that correspond to the constituents of the compound.

Previous studies of patients with acquired language impairments have documented cases of German-speaking patients whose performance in naming (Hittmair-Delazer, Andree, Semenza, De Blesser, & Benke, 1994) or repetition (Stark & Stark, 1990) showed sensitivity to the compound status of the words that could not be named or repeated. Delazer and Semenza (1998) present an Italian-speaking patient whose naming difficulties are largely restricted to compound targets, and whose responses to compound targets are reliably viable Italian compounds. The case study presented here describes an English-speaking patient whose errors in identifying objects with compound names help to adjudicate between the whole-word and composition models of compound production. I will argue that this patient's naming performance provides compelling support for the compositional approach to compound production even when the meaning of the constructed word is not predictable from the meaning of its parts.

[3] The addressing convention employed in Figures 1 and 2 is purely arbitrary, and would be just as appropriately characterised as an explicit link between lemma and lexeme components in a localist network. In addition, the syntactic information associated with each lemma has also been omitted for purely expository purposes.

CASE STUDY

CSS is a 65-year-old, right-handed (though somewhat ambidextrous) male, with three years of college education who was employed as an engineer. CSS suffered a left cerebro-vascular accident in May 1990 resulting in lexical impairments manifested in reading, repetition, and oral and written naming tasks. Apart from his word-finding difficulties, CSS's spoken output is fluent and he exhibits no apparent comprehension impairment. In a synonym-matching task with abstract and concrete nouns, CSS performed with 100% accuracy. Auditory lexical comprehension, tested using a picture/word matching task with pictures from Snodgrass and Vanderwart (1980), was not detectably impaired (100% accurate). CSS's performance on the Peabody Picture Vocabulary Test (auditory presentation of words) placed him in the 42nd percentile.

CSS's performance in reading aloud was good, although it was not error free (from 88–94% correct across different testing sessions for mixed classes or words). His reading errors include the production of semantic paraphasias (e.g., **hairless** → *bald*), visual/phonemic paraphasias (e.g., **exception** → *execution*) and non-lexical phonemic paraphasias (e.g., **antlers** → [ændɚz]). In addition, he produced morphological errors in reading affixed words (e.g., producing both legal forms as in the error **seriousness** → *seriously*, and morphologically illegal forms as in **swiftness** → *swiftless*) and neologistic compounds when reading compound targets (e.g., **seaport** → *sea boat*; and **highway** → *hard way*). His moderately good performance on non-word reading tasks (74% correct, $N = 155$), and the fact that he exhibits a marginal effect for orthographic regularity in word reading (93% vs. 80% correct on regular and irregular, respectively), suggest that his low error rate in reading words may in part reflect the contribution from a preserved capacity to generate phonological forms using non-lexical, grapheme-to-phoneme mapping procedures.

In picture naming tasks using materials from Snodgrass and Vanderwart (1980) and the Peabody Picture Vocabulary Test, CSS made both lexical and non-lexical phonological paraphasias (e.g., **television** → *telephone* and **trumpet** → [trúpɪt], respectively) and semantic paraphasias (e.g., **fork** → *spoon* and **leg** → *elbow*). A notable feature of his naming performance, though, relates to the morphological structure of an object's name. CSS appeared to have more difficulty naming objects with compound names (e.g., **seahorse**, **light house**) than naming objects with mono-morphemic or suffixed names (e.g., **accordian**, **radiator**), and he produced neologistic compounds in response to some compound targets (e.g., **snowman** → *snow wheel*; **skyline** → *sunline*; and **ski lift** → *ski light*). In order to test the reliability of this performance pattern, CSS was administered a more extensive naming battery designed to assess performance on compound and mono-morphemic targets.

Naming battery

CSS was administered two naming tasks with compound and mono-morphemic targets: picture naming and naming-to-definition. In the picture naming task there were 322 items with compound targets, and 368 items with mono-morphemic targets. However, in order to compare CSS's performance on compound and mono-morphemic targets, it is necessary to control for target frequency, length in phonemes, and length in syllables. Error rate analyses were carried out comparing CSS's picture-naming performance on compounds ($N = 322$) to a subset of the mono-morphemic targets ($N = 166$) in the same frequency range as the compounds (5.6 vs. 5.1, $t < 1$) and list-matched to the compounds on length in syllables and phonemes. The naming-to-definition task consisted of definitions for 250 compound targets and 150 mono-morphemic controls. The compound and mono-morphemic items were list-matched for syllable length, and were drawn from the same frequency range: Mean frequency for the compound and mono-morphemic items was 7.4 and 10.9, respectively ($t < 1$). In order to reduce possible list effects on error types, the stimulus items in the naming-to-definition task were embedded in a larger list of definitions for targets that were entirely mono-morphemic ($N > 300$).

Error rates for compounds and mono-morphemic words

CSS's performance on the picture-naming and naming-to-definition tasks was much better with mono-morphemic targets (79% correct) than with compound targets (50%). This pattern holds when we consider each of the naming tasks separately. In the picture naming task, CSS was 77% correct in naming the mono-morphemic targets, but only 53% correct for the compounds ($\chi^2 = 26.16$, df $= 1$, $p < .001$). The same asymmetry was observed in CSS's performance on the naming-to-definition task: He was 80% accurate with the mono-morphemic targets, but his performance dropped to 47% correct for the compound items ($\chi^2 = 35.35$, df $= 1$, $p < .001$).

A frequency analysis was carried out on the compound items that are orthographic single-words (e.g., *seahorse*) using the U value from the Carroll, Davies, and Richmann (1971) frequency count, in order to assess the contribution of this lexical factor. When the whole-word frequency of compounds that induced picture naming errors was compared to the frequency of the items CSS named correctly, there were no apparent effects for frequency: The mean frequency of error-inducing targets was 5.7, while the mean frequency of the targets CSS named correctly was 5.5. Similarly, the frequency of the targets named correctly in the naming-to-definition task did not differ from the frequency of the error-inducing targets (8.5 vs. 6.5; $t < 1$). Hence, while the frequency of an item may not be entirely irrelevant to CSS's performance, it cannot account for the asymmetry between compound and mono-morphemic targets in naming. (Frequency analyses involving the constituent elements of the target compounds and compound errors are discussed below).

The first real difficulty that the whole-word retrieval approach to compound production faces is that there is no apparent reason why there should be a higher error rate on one type of stored word than on another. One might appeal to the internal (i.e., morphological) structure of the different target types in order to distinguish them. However, in the absence of an account of how and why this encoding of morphological structure plays a role in (what is by hypothesis) whole-word retrieval, citing this distinction merely begs the question of why the morphological contrast is reflected in different levels of performance in picture naming and naming-to-definition.

Error analysis

CSS's first responses to the compound items and mono-morphemic control items from the picture-naming and the naming-to-definition tasks were analysed in terms of error types. In addition to a difference in error rate, there were also striking differences in the types of errors that were induced by compound and mono-morphemic targets in the two naming tasks. For mono-morphemic targets, the dominant error type for first response was semantic (49%), followed by phonological word errors (25%) and phonological non-word errors (18%). (Error proportions are based on the first lexical response, if there is one.) Examples of these error types are given in Table 1.

When first examined, the errors that CSS produced when the target was a compound appear quite different from those exemplified in Table 1. The dominant error type for compounds is a specific variety of partial response that will be referred to as component errors (i.e., a lexical response corresponding either to the first or second conjunct of the target compound; 52%). In addition to component errors, CSS's errors for compound targets included compound neologisms (17%), other compounds (10%), and semantic errors (7%). Examples are provided in Table 2.

While the errors for mono-morphemic and compound targets are superficially different, we shall see from the analysis of CSS's compound

TABLE 1
Types of picture-naming errors for mono-morphemic words

Semantic errors		
crab	→	lobster, clam
globe	→	atlas
parachute	→	balloon
Phonological word errors		
radiator	→	refrigerator
raccoon	→	baboon
penguin	→	pendulum
Phonological non-word errors		
wrist	→	[rɪsp]
robot	→	[rómat]

neologisms that there are some important similarities that become apparent when one views the constituents of the compound (rather than the compound as a whole) as the relevant terms of analysis. First, though, we discuss the dominant error type for compound targets: component errors.

Component errors. The production of a component error might at first be taken to suggest that the mono-morphemic response competes on an equal footing with the compound target. However, there are at least two features of these errors which, together, indicate that CSS was aware that the target form was a compound (and that the lexical item that comprises the component error is only a part of the target form). First, the

TABLE 2
Types of picture-naming errors for compound words

Component errors		
sundial	→	sun
grasshopper	→	grass, +
lighthouse	→	[lays], light, +
Compound neologisms		
seahorse	→	water horse, horse water
snowshoe	→	shoe snow
Other compounds		
stop watch	→	time clock
bagpies	→	windpipes
Semantic errors		
landlord	→	tenant
doorknob	→	latch

component errors were frequently followed by correct responses or other compound responses. For example, of the 85 picture-naming trials scored as component errors, 82 (96%) were the first lexical response in a sequence of naming attempts that resulted either in the correct compound (e.g., **pineapple** $\rightarrow$ *pine*, *pineapple*: $N = 51$; 62%) or in neologistic compound (e.g., **sundial** $\rightarrow$ *sun*, *sunclock*, *sun watch*: $N = 31$, 38%). Second, the prosodic form of the component error virtually always suggested that CSS was aware that the response was incomplete and that there was a missing word. Occasionally, this cognisance was also evident in CSS's use of an empty compound component, as in **slowdown** $\rightarrow$ *something down*, **weather vane** $\rightarrow$ *air something*, and **seahorse** $\rightarrow$ *horse something*. So, despite the fact that the first lexical response was mono-morphemic, the component errors in the naming tasks manifest a processing stage at which there is information regarding the incompleteness of the response.

Additional analyses were carried out on the 171 first responses scored as component errors in order to examine the influence of order and relative frequency of the components of the target compound. The number of preserved first constituents and second constituents in CSS's component errors are indicated in Table 3.

Overall the first constituent of a compound (rather than the second constituent) is the first partial response ($\chi^2 = 15.56$, df $= 1$, $p < .001$). Since the items in these naming tasks are predominantly noun-noun compounds, it is implausible that this asymmetry derives from a grammatical category effect. Nor does the tendency to produce the first constituent in a component error appear to be derived from frequency differences between the first and second constituents of the targets that CSS could not name, as the frequency analyses discussed below will make clear.

In themselves, component errors do not provide a strong indication that the means for producing compounds involves compositional mechanisms (as opposed to whole-word procedures). For example, one might instead suppose that these responses correspond to the intact portion of a partially retrieved, whole-word representation that is augmented with information regarding the morphological structure of the target. Nevertheless, it is

TABLE 3
Number of preserved first constituents (C1) versus preserved second constituents (C2) in CSS's component errors

	C1	*C2*
Picture naming	61	24
Naming to definition	50	36
Total	111	60

noteworthy that whereas component errors were a dominant first response type for compound naming errors (52%), an account of these errors which analyses them as incomplete retrieval of a whole-word representation would lead one to expect a comparably high rate of responses to mono-morphemic targets in which only part of the phonological form can be retrieved (e.g., as in the error **octopus** $\rightarrow$ [akto], *octopus*). In fact, there were very few errors of this type ($N = 4$, 6% of error responses to mono-morphemic targets), and there were no occasions where CSS produced an embedded word response to a mono-morphemic target (as in the hypothetical error **pendulum** $\rightarrow$ *pen*). Minimally, then, these features of the component errors indicate that CSS has access to information regarding the morphological structure of compound targets even when his initial response is limited to a partial, albeit lexical, response. More direct evidence for a compositional approach to compound production derives from the compound errors that CSS produced.

Neologistic compounds. There are several features of the neologisms produced to compound targets which indicate that an underlying compositional mechanisms is at work. In particular, these relate to (1) the morphological status of target word, (2) the nature of the substitutions internal to the compound, and (3) the order of the components in the compound. It should be noted that CSS produced neologistic compounds in picture-naming, naming-to-definition, reading, and repetition tasks. However, in order to rule out any potential contribution of deficits to lexical input processes, the analysis examines only those neologisms observed in the picture-naming and naming-to-definition tasks. In order to gain a clearer picture of this error type, the analysis of CSS's compound neologisms will include all such errors in the error corpus for picture-naming and naming-to-definition (i.e., not just first responses).

1. Neologistic compounds and the morphology of the target. As indicated in Table 4, a stable features of CSS's performance is that the compound neologisms were virtually always produced in response to a compound target (98%).

Clearly, compound neologisms are the product of a compositional procedure: The lexicon should not contain entries that would permit the neologisms to be retrieved. The fact that these errors are evoked by compound targets (but not non-compounds) indicates that some features of the compounds initiates the compositional procedure evident in these errors. Note that it cannot be the prosodic structure of the compound that accounts for this asymmetry, because words that were both mono-morphemic and polysyllabic did not induce this error type. The morphological structure of the target is the clear candidate.

TABLE 4
Number of compound neologisms produced in response to compound and mono-morphemic targets (and number of compound and multisyllabic mono-morphemic controls in the naming materials)

	Compound targets	*Mono-morphemic targets*
Picture naming	60 ($N = 322$)	2 ($N = 166$)
Naming to definition	59 ($N = 250$)	0 ($N = 150$)
Total	119 ($N = 572$)	2 ($N = 316$)

2. Substitutions in neologistic compounds. The production of compound neologisms involved in the same types of lexical substitutions *internal to the compound* that are observed in CSS's naming errors for mono-morphemic targets. For mono-morphemic targets, CSS produced phonological paraphasias and semantic paraphasias (cf. Table 1). Setting aside misordering errors for a moment, the substitution errors in neologistic compounds involve the insertion of a word that is phonologically related to the component that it replaces, or semantically related to either the entire word or (in very few instances) to the component it replaces. Examples are given in Table 5.

There are no apparent differences between the types of phonological errors that were produced in response for mono-morphemic targets (**calendar** → *calliper*; **caterpillar** → [kætɚpɪlo]) and those produced as part of a response to a compound target (**duffel <u>bag</u>** → *duffel <u>bug</u>*; **<u>measuring</u> cups** → [mɛzɚlɪn] spoons). Phonological word and non-word errors for both types of targets tended to match the target form in number of syllables; and in the case of polysyllabic targets, both phonological word and phonological non-word errors tended to match the target in stress placement. Of the phonological word errors, 91% (31/34) were equal in

TABLE 5
Substitution types internal to neologistic compounds

Phonologically based substitutions		
stage *coach*	→	stage *coast*
doll house	→	*tool* house
weight *lifter*	→	weight *loafer*
Semantically based substitutions		
ashtray	→	ash *vase*
wheelchair	→	wheel *pill*
cheer leaders	→	*gym* leaders

length to the target form in syllables; while for the non-word errors, 85% (40/47) matched the target length in syllables. Furthermore, when the target and error were both polysyllabic, 98% of the errors exhibited the same stress pattern as the target (one non-word error did not). Stressed syllables were no more likely to be produced correctly than unstressed syllables in CSS's non-word phonological errors; but for his word errors, stressed syllables elicited fewer errors than unstressed syllables ($p = .015$, Fisher's Exact Test).

In the case of semantic substitutions, the errors for mono-morphemic targets (e.g., **crab** → *clam*) were by and large similar to those which occurred as part of a response to a compound target (**sundial** → *sun clock*, *sun watch*, +). Table 6 provides a summary of the types of relations that exist between the components of the target and the components of the neologistic compounds. As the figures in the table indicate, the most frequent substitution types involve items that are semantically related to the whole-word (as in **southpaw** → *southball*; 43% of the component substitutions) or phonologically related to a constituent of the target compound (as in **dragonfly** → *dragon fire*; 25% of the component substitutions).

Another noteworthy feature of the substitutions is that the lexical items that intrude in the error compete with the components of the compound, and not with the compound as a whole. This is not surprising in a system in

TABLE 6
Relation between the components of compound targets and the components of neologistic compounds in naming errors (C1 = first constituent, C2 = second constituent)

	Compound constituent	
	C1	*C2*
Correct	53	34
Ordering errors (i.e., C1→C2 or C2→C1)	20	12
Phonologically related to		
C1	17	4
C2	1	17
Semantically related to		
C1 only	4	5
C2 only	1	5
whole word	32	44
Other	1	8

which compounds are produced by calling up separate lexical forms and inserting each of the retrieved representations into one of two structural positions. However, if this feature of the neologistic compounds were merely the product of a strategy to fill in an underspecified portion of a (partially) retrieved form, one would also expect to see lexical substitutions for parts of mono-morphemic words (as in the hypothetical errors **penguin** → *pen-bird* or *pen-ice*). Significantly, such errors do not occur.

One could argue that the absence of such errors for mono-morphemic targets is consistent with a whole-word retrieval account if the stored representation of lexical forms specifies its morphological structure. But a different problem arises for the variant of the whole-word retrieval model in which the lexical system differentiates stored forms for mono-morphemic and compound words in this way. Form-based substitutions typically involve the intrusion of competing forms that are similar to the entire target form (e.g., **raccoon** → *baboon*). So, while the augmented version of the whole-word based approach to production provides a way to limit hypothetical filling-in errors to morphemic constituents of compounds (i.e., allowing a lexical substitution to replace a part of the target, and not just the entire target), the competitor should still be a form that is related to that of the entire target. But this would lead to the production of errors like **overcoat** → *acrobat coat* (where *overcoat* and *acrobat* are alike in prosodic structure). Errors of this sort also do not occur.[4]

Frequency analysis. The compound targets that elicited component errors and compound neologisms in which one target constituent is preserved were analysed for the effect of lexical frequency. Only first responses are analysed.

One aspect of CSS's component responses which may appear problematic for the analysis proposed here is that it was virtually always the case that the form that CSS produced in a component error was more frequent than the target compound. This is not surprising, of course, since the frequency asymmetry holds for virtually every compound and its constituents. However, one might argue on the basis of this frequency

[4] David Caplan (personal communication) noted that CSS's compound neologisms might not reflect a normal compositional process: Instead, it might be that the lexical form which intrudes in these errors arise post-lexically (during the process of phonological planning). If access to the components at this stage could be the result of the pathology, this would undermine the argument for a compositional approach in the normal system. The problem with this counter-proposal is that it too fails to account for why CSS never produced analogous errors for mono-morphemic targets. For example, although there were only few ($N = 12$) pseudo-compounds in the corpus of mono-morphemic targets CSS was asked to name (e.g., **canteen**, **tulip**, **sandwich**), he never substituted a pseudo-constituent in these words. Many more words contained embedded words (e.g., **barber**, **walrus**), and sublexical word intrusions were absent here as well.

asymmetry alone that the component errors represent instances of whole-word substitutions in a system that stores compounds in a whole-word form. There are two difficulties with this suggestion, though. The first is that it fails to explain one of the most salient features of these errors: the fact that component errors were produced with a prosodic form indicating that the response was incomplete (rather than with the falling contour that accompanied a non-component error or correct response to either a compound or mono-morphemic target). Analysing component errors as simple whole-word substitutions cannot explain why CSS's prosody signalled component errors (but not other error types) as incomplete responses. The second difficulty with interpreting component errors as instances of whole-word substitutions is that form-based errors to non-compounds, unlike component errors, virtually always matched their targets in length (in syllables), while component errors, by definition, never did. If component errors were in fact form-based whole-word substitutions, as opposed to constituent omissions, as hypothesised here, then the fact that CSS's form-based substitutions differed as a function of the morphology of the target would itself be a mystery. Hence, it would be unreasonable to take the frequency advantage that component errors possessed as support for a whole-word approach to compound production.

Two additional frequency analyses were carried out. First, the frequency of the preserved component of the target compound (in both component and neologistic errors) was compared with the frequency of the target component that was not preserved in the error. Overall, there was no apparent effect of frequency on this analysis: The preserved component was more frequent than the non-preserved component in 51% of CSS's component errors and compound neologisms ($N = 152$). The number and proportion of such responses for each error type are indicated in Table 7.

This analysis makes it quite clear that the facts concerning constituent order and the preserved element in component errors (i.e., that component errors tend to consist of the initial constituent of the target compound)

TABLE 7

Number (and proportion) of responses scored as component errors and compound neologisms in which the frequency of the preserved constituent was greater than the frequency of the constituent that was not preserved in the error

	Component errors	*Compound neologisms*
Picture naming	48 (.54)	37 (.54)
Naming to definition	45 (.42)	22 (.55)

cannot be explained in terms of the relative frequency of preserved and omitted items. More generally, lexical frequency appears not to play a dominant role in the relative availability of the two constituents of the target compounds that CSS has trouble naming.

Compound neologisms were also analysed for the relative frequency of the error portion of the neologism and the non-preserved portion of the target. For example, in the error **honey comb** → *honey pin* the frequency of the target component **comb** was compared to the frequency of the neologistic component **pin**. The frequency of the intruding component (e.g., **pin** in the example) was greater than the frequency of the target component (**comb** in the example) in only 47% of the neologisms ($N = 59$), providing further evidence that frequency did not play a controlling role in CSS's responses to compound targets.

3. Order within neologistic compounds. Although compound neologisms often reflected the successful retrieval of one component of the target, this correct subpart did not always occur in the appropriate position in the response. As the examples of ordering errors provided in Table 8 indicate, constituent misordering was also observed in errors in which both target constituents appear in the response.

When the two components of the compound are both available to the processing system, the whole-word retrieval account would lead one to expect that their order will be preserved. This was not always the case, however, as attested by CSS's errors **postbox** → *box post*, **shoetree** → *tree shoe*, **fire wood** → *wood fire*, and others. Furthermore, misorderings of non-lexical constituents for mono-morphemic targets (e.g., permutations of syllables or feet, as in the hypothetical errors or **trumpet** → *pet-trum*, or **ballerina** → *ina-baller*) were never observed. Hence, it cannot be that the ordering errors for compounds are merely the consequence of damage to (some as yet unspecified) compositional mechanism that operates at the level of phonological form. The misorderings are observed only when the

TABLE 8
Examples of ordering errors in compound neologisms

trash can	→	*can trash*
snow shoe	→	*shoe snow*
pin cushion	→	stop *pin*
light house	→	tree *light*
teddy *bear*	→	*bear* baby
weather *map*	→	*map* temperature

morphological structure of the target provides two lexical slots for its components.

While these errors would be difficult to explain if compounds were produced by means of whole-word retrieval mechanisms (since, by hypothesis, the only misorderings observed would be those of the lexical constituents internal to the putatively retrieved form), the misordering of compound constituents can be accounted for relatively straightforwardly by positing a deficit to a mechanism that composes compounds out of their lexical components. In particular, the compositional mechanisms must associate each of the two retrieved lexical forms with a specific position in the compound structure, and the loss of information concerning the links between the lexical items and their target positions may result in misordering.

Productivity vs. semantic predictability

To the extent that CSS's compound neologisms motivate a compositional apparatus for compound production, they also help address the issue of when compositionality will be reflected in the production system. On one view, a productive morphological process will be consistent with formal composition in the output system only if the semantics associated with the complex morphological form can be predicted from the semantics of the components of that form. Alternatively, whether or not the compositional approach is invoked will be determined by the productivity of the word formation process. With regard to this contrast, it is telling that CSS's compound neologisms are not limited to targets whose specific meaning is transparently related to the meaning of its constituents. As the examples in Table 9 indicate, these errors are also observed when the meaning of the compound is not fully accounted for by the meanings of the compound's constituents.

In fact, the targets in the examples in Table 9 are merely extreme instances of what is generally true of compounds: The meaning of a (root) compound is not fully determined by the content of the lexical constituents and the rules of compounding. Nevertheless, the neologistic errors

TABLE 9
Compound neologisms for semantically opaque compounds

butterfly	→	butter flower
downpour	→	down storm
sundial	→	sunclock
southpaw	→	southball
dragonfly	→	doctor fly, tiger wing
sea horse	→	fish horse

exemplified here suggest that rule productivity induces composition at the level of form even when semantic transparency is not a property of the output of the compositional process.

SUMMARY AND DISCUSSION

CSS's naming errors indicate that the lexical system must (in some way) specify the morphological structure of compounds. This is most clearly revealed by CSS's compound neologisms, in which the constituents of a target compound are replaced by forms that are semantically related to the whole word (e.g., **downpour** → *down storm*) or phonologically related to the omitted constituent (e.g., **dragonfly** → *doctor fly*), and/or the order of the target constituents is not preserved (e.g., in errors where the preserved constituent is not in its target position: **pin cushion** → *stop pin*; and in errors where both constituents are present, but in the wrong order: **fortune teller** → *teller fortune*). These substitutions and misorderings were produced in response to compound targets, but are not observed when CSS misnames objects with mono-morphemic labels. If the lexical system did not differentiate the morphological structure of compounds and non-compounds, there would be no account for this performance asymmetry. Moreover, these errors, along with other features of CSS's naming performance, provide crucial evidence regarding how compound structure is reflected in the production system. In particular, CSS's performance provides support for a compositional approach to producing (root) compounds, rather than for a production system based entirely on the retrieval of whole-word forms that are augmented with morphological information.

If the compound structure were only specified in a stored (whole-word) form, then one might be able to account for some features of CSS's component errors that manifest an awareness of the morphology of the target (i.e., the fact that the prosody of the response indicates CSS's awareness of a target's structure, and that these partial responses are usually followed up with a compound response). For example, if a partially retrieved form includes a structural specification of the form, then this might serve as the basis for such performance features. While this would address CSS's cognisance of the target structure, though, it would not shed any light on the difference in his naming accuracy for compound vs. mono-morphemic targets. In addition, the whole-word retrieval account provides no reason to expect errors involving the ordering of word-internal constituents for compounds (but not mono-morphemic targets), nor does it explain the parallels between the whole-word substitutions for mono-morphemic targets, and the word-internal substitutions in the neologistic responses to compound targets. In the absence of an explanation of how the internal (specifically, morphological) structure of a stored, whole-word representation of a compound induces these error characteristics, or how it renders compounds more difficult to retrieve than stored, non-compound forms, the whole-word processing account (even in this augmented form), faces serious difficulties.

In contrast, a processing model that includes compositional mechanisms for the production of compounds provides a more or less straightforward account of the differences in naming accuracy for compound and non-compound targets, and also of the types of substitution errors that, at first blush, appear to be specific to compound targets. If some or all of the mechanisms associated with composition (structural specification for the compound frame, retrieval of the individual component forms, and the linking of each form to the appropriate structural position in the compound frame) are implicated in CSS's naming deficit, then many of the features of CSS's naming performance on compound targets will follow. To begin with, one must posit a deficit in retrieving forms in the output lexicon in order to account both for the whole-word substitutions he produces for some mono-morphemic targets, and also for the (sub)lexical substitutions we observed in the case of the compound neologisms he produces. Note that the substitutions in both cases are semantically and phonologically based substitutions: The only difference between the two situations is that in the case of CSS's neologistic responses to compound targets, the semantically related form competes with a sub-constituent of the target, and not the entire lexical target. Given that our model of lexical representation distinguishes the kind of whole-word entry for a compound at the lemma level from the composite representation at the level of form, it is also noteworthy that the sublexical replacements in the neologisms involve different relations to the target for the semantic and form-based substitutions. With the semantic substitutions, the intruding form tends to be related in meaning to the compound as a whole, whereas in the form-based replacements, the intruding form is phonologically related to the form it replaces (and not to the entire compound target).

If one further posits a disruption to the processing routines for the linking procedures that are called up by the complex pointer for a compound (Figure 2), then certain additional features of CSS's performance follow: These linking procedures must function properly in order to associate the constituents of the compound with the appropriate (sublexical) positions; and a breakdown in their functionality would account for the compound-internal misorderings in some of CSS's neologisms. This hypothesised disruption to the linking procedures would also be expected to contribute to CSS's lower accuracy for compounds, though more will need to be said about the difference between his naming of compound and mono-morphemic targets. Before we can do so, though, it would be useful to consider the relationship between CSS's retrieval deficit and the types of substitutions that occur in his naming errors.

The principal issue we face in analysing CSS's substitution errors, both the full substitutions observed in naming trials with mono-morphemic targets and the partial substitutions on trials with compound targets, is this: Do CSS's semantic substitutions arise from a semantic deficit (i.e., as a consequence to a level of representation organised in terms of meanings), or does the deficit that is responsible for his form-based errors also cause the production of semantic paraphasias? One piece of evidence regarding the origin of CSS's semantic substitutions derives from the high level of his performance on comprehension tasks. If the semantic paraphasias he produced in naming tasks derived from a semantic deficit, then one would anticipate impaired performance in comprehension tasks as well. Instead, we find that CSS performed perfectly in a picture/word matching task that employed the very same picture materials that induced semantic (and other) paraphasias in naming tasks. On a variant of the account discussed by Caramazza and Hillis (1990), one would expect that semantic paraphasias could also arise as a consequence of a deficit affecting the retrieval of phonological forms: If the semantic features that are used to select (or activate) a representation in the lemma system also activated semantically associated representations at this level, then these other representational units might act as competitors when the phonological form corresponding to the target cannot be retrieved. Given that the two substitution types in CSS's naming errors can both be explained by an impaired ability to retrieve lexical forms, and that there is no evidence of a semantic deficit, it would seem reasonable to attribute both his semantic and his form-based substitutions to such an impairment.

Returning to the issue of CSS's naming accuracy, we can now ask if the hypothesised disruption to the linking procedures, in combination with the unitary account proposed for his substitution errors, is sufficient to account for the asymmetry in his naming compound vs. mono-morphemic targets. Recall that the dominant error type observed in CSS's first responses is the component error. Although there is a general tendency for component errors to correspond to the first constituent of the target compound, the second constituent of the target compound comprised 35% of the responses scored as component errors. Furthermore, when the component error did correspond to the first target constituent, CSS's follow up responses on occasion placed this constituent in second position in a neologism or a filler compound (e.g., **lighthouse** → *light*, *tree light*). Both of these facts suggest that information regarding the structural position of a constituent was degraded. More generally, CSS's neologistic compounds included a misordered constituent more than 18% of the time (where either the single preserved constituent in the error is misordered: **pin**

cushion → *stop pin*; or both constituents appear in the wrong position: **postbox** → *box post*). This 'linking' deficit might also have consequences beyond those relating to apparent cases of misordering: If the successful retrieval of multiple lexical forms depends in part on having a designated structural position for each of the lexical targets, then the under-specification of order could amplify the difficulty the system faces with regard to form retrieval for compounds (in comparison to mono-morphemic targets). Even apart from this contributing factor, though, one must also note that, on the compositional account of compound production argued for here, compounds provide twice as many opportunities for form retrieval to break down as do mono-morphemic targets. Hence, it seems plausible that CSS's impaired naming of compounds derives from this simple combination of impairments: from a deficit affecting form retrieval (for both non-compounds and compound constituents), from a breakdown in linking retrieved forms to positions in the target frame, and possibly also from the amplifying effect that this linking difficulty has on the deficit that influences form-retrieval in general.

The two-stage model of production

The performance model utilised and refined here in order to explain CSS's naming performance is a two stage model of lexical production that has been argued for based on a substantial range of experimental evidence, including speech error data (Garrett, 1980, 1982), results from chronometric studies of picture naming (Levelt, Roelofs, & Meyer, 1999), data from anomic patients (Badecker, Miozzo, & Zanuttini, 1995), and studies of Tip-of-the-Tongue (TOT) phenomena (Vigliocco, Antonini, & Garrett, 1997; Vigliocco, Vinson, Martin & Garrett, 1999). There are different variants of the two-stage model, and the differences relate for the most part to whether the lemma is conceptualised as a content-less binding node (e.g., Dell, 1986; Levelt et al., 1999), or a complex representation that includes the grammatical features of a word (Garrett, 1980, 1982). In each version of this model, though, the lemma is construed as a lexical representation (or processing unit) that must be accessed by input from the conceptual-semantic system. It specifies the grammatical properties of the lexical item (in some instances by serving as the processing unit that binds the particular grammatical features together as part of a single lexical representation); and it serves as the basis for gaining access to the lexeme. Furthermore, there is no direct connection from the conceptual-semantic system to the lexemes; access to the lexeme for a word requires the intermediate activation of its lemma.

Notwithstanding the broad acceptance of the two-stage model in the production literature, this model has not gone unchallenged. One important counter-proposal is the independent network (IN) model of lexical production proposed by Caramazza (1997). On this model, lexemes are linked directly to distributed semantic representations and also to grammatical features. Grammatical features that are highly correlated with semantic properties (e.g., category features like Noun and Verb, and nominal features like Count vs. Mass) may receive direct, albeit weak input from the semantic network. These features are also activated via the strong link connecting them to the lexeme. Grammatical features that do not have the semantic motivation, such as the gender features for nouns referring to inanimate objects, are linked only to the lexeme itself. Caramazza (1997) argues that many of the data that have been taken as support for the two-level model are in fact compatible with the IN model of lexical production, and that some of these (e.g., the fact that speakers in TOT states appear at times to have access to information about the target's phonology on occasions that they do not have ready access to putative lemma-level information like grammatical gender) would seem to favour the IN model over the two-level model of production (though see Vigliocco et al., 1999, for a response to this point). Although a complete discussion of this counter-proposal is beyond the scope of the present paper, it is worth considering how well the IN model fits with the data presented here. Caramazza's (1997) exposition of the IN model deals with the production of mono-morphemic words, but it is plain that this model could be extended to cover at least some cases of morphological composition at the level of form. In particular, if a morphologically complex target is suitably compositional at the semantic level (as with the regular past tense form **walked**), one could argue that the semantic features corresponding to the verb stem will serve to activate the corresponding lexeme (**walk**), that the past tense meaning will activate a representation corresponding to the affix (**-ed**), that the stem and affix lexemes are linked to grammatical features that license their conjunction, and that among the grammatical features associated with the affix will be a specification of its suffix status (therein determining the mode of combination). The two critical features of such an approach to producing regularly inflected forms are the semantic compositionality of the complex form, and the rule-like status of the affixation process. A grammatical feature which identifies a unit of form as a suffix (or as a prefix) can be exploited to direct the combinatorial process. The parallels between inflection and conventional compounding are less than perfect, though, and it is because of this that the IN model would appear to run into trouble with the pattern seen in CSS's naming performance.

There are two senses of 'compositional' that must be distinguished when speaking of the semantics of morphologically complex words. There is an informal sense in which a compound like **lighthouse** may be considered compositional: A lighthouse is a building atop of which a beacon is positioned for the purpose of guiding mariners around navigational hazards, and this complex body of information is manifest in the meaning of the compound. In this sense, which might better go under the description's 'componential', the meaning of the compound is 'composed of' component meanings each of which may have its own means of independent expression. There is also a more formal sense of this term whereby the complex meaning of an expression is said to be compositional if that meaning is fully predictable from the meaning of its parts and the way in which those parts are combined. In this sense, the meaning of a conventional compound like **lighthouse** would fail to be compositional. The importance of this distinction is that the meaning of a compound cannot determine its compound status. As Hittmair-Delazer et al. (1994) pointed out, the meaning of **butterfly** is the meaning of **papillon**, which is a French monomorphemic form. Other English compounds have synonyms that are mono-morphemic (e.g., **suitcase/valise**, **handbag/purse**, **hot chocolate/cocoa**, **hotdog/frankfurter**, **daybreak/dawn** and **icebox/freezer**). So, the prospect of having the meaning of these compounds serve as the device by which the two lexemes get treated as parts of a single word seems to have little chance of succeeding. By the same token, the activation of two lexemes must be treated differently if the lexemes are competitors (as with **horse** and **mare**) or parts of a compound (as with **horse pill**). This is work that cannot be done by simple activation links between the lexemes and a compound frame, because these lexemes must also function as the form-level representations for the words when they appear alone. In other words, the conventional status of the compound requires that there be a representational unit that binds all of the components of form together into a single lexical item (along with specifying *how* those components must be combined). This might not be a problem for the IN model if the components themselves were not lexemes, but some prosodically defined representational unit that the lexeme could itself call up. This is because lexemes are the only relevant binding units available in this model, and so the sublexical units that are replaced in compound neologisms could not be lexemes themselves. However, the evidence from CSS suggests that the sublexical units that are implicated in his neologistic errors *are* lexemes. CSS's performance indicates that the compound **lighthouse** is not stored as single lexeme (i.e., that it is not separate from the lexemes **light** and **house**). This means that some other type of unit must bind these pieces of form together for the particular lexical meaning. If it cannot be the meaning itself, then the binding node must be an intermediate representation between conceptual/semantic representation and lexeme – i.e., the lemma. So, to the extent that CSS's naming performance supports a model in which a compound is produced by calling up the separately stored lexemes corresponding to its two parts, this performance also provides support for the two-level model of lexical production.

In summary, the case for a lexical system that includes compositional procedures for the production of compounds is bolstered by CSS's naming performance. This is especially significant in that while the type of compounding examined here – root compounding – is morphologically productive, the output of this process results in an association of meaning and form that cannot be predicted from the ingredients of the word structure. That is, unlike the cases of regular inflection and productive derivation, where the meaning of the whole is entirely derivable from the meaning of the constituents and the word formation process in question, the meaning of a compound cannot be similarly determined. In the extreme case of compounds like **butterfly**, **downpour**, and **southpaw**, the relationship between the meaning of the whole and the meaning of the parts can be quite unpredictable. However, even when the meaning of a compound is less opaquely related to the meaning of its constituents (as in compounds like **lighthouse**), the word's meaning goes beyond what can be specified by rule. That is, it is the general case for root compounds that their semantics must be specified on a word-by-word basis. Hence, if the treatment of compositionality at the level of form were determined solely by the transparency of the meaning-form relation, a pattern of naming such as that observed with CSS would be at odds with the organisation of the lexical production system. What CSS's performance points to instead is a lexical system in which composition at the level of form is determined by the productivity of the particular word-formation process.

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APPENDIX

Examples of compound targets from picture naming and naming to definition tasks:

Picture naming targets: air conditioner; angel fish; ashtray; bagpipe; baseball; basketball; beehive; bird cage; birdhouse; bobby pin; bow tie; briefcase; bulldozer; bunk bed; butter dish; butterfly; can opener; ceiling fan; chainsaw; checkbook; chessboard; clipboard; clothespin; coffee maker; cookie cutters; corkscrew; cowboy; diving board; dragonfly; driveway; dust pan; egg beater; egg carton; eyebrow; eyelash; fingernail; fingerprint; fireman; fireplace; fireworks; fishbowl; flashlight; football; forklift; frying pan; golf club; grapefruit; grasshopper; hair dryer; hairbrush; hamburger; handbag; handcuffs; headboard; headlights; headphones; honeycomb; horseshoe; hot dog; ice skate; jump rope; jumpsuit; keyboard; knitting needles; ladybug; lawn mower; lighthouse; lipstick; mailbox; mailman; matchbook; matchbox; milkman; mousetrap; movie projector; newspaper; nutcracker; overalls; palm tree; peanut; piggy bank; pin cushion; pine cone; pineapple; pocketknife; rainbow; raincoat; remote control; rocking chair; roller skate; scarecrow; screwdriver; seahorse; seat belt; shoe horn; shoe rack; shoulder pad; skyscraper; sleeping bag; slingshot; snowman; snowmobile; snowshoe; soccer ball; spider web; sports car; spotlight; stage coach; station wagon; steak knife; stepladder; stop sign; stopwatch; suitcase; sundial; surfboard; tablecloth; taillights; tape deck; teapot; teaspoon; teddy bear; thumb tack; toll booth; toothbrush; toothpaste; totem pole; tow truck; trash can; turntable; typewriter; vacuum cleaner; waterfall; weather map; weightlifter; wheel barrow; wheelchair; wood pecker

Naming to definition targets: background; backyard; bathtub; beehive; birdbath; birdhouse; blackberry; bookshelf; broomstick; buckwheat; bullfight; buttercup; butterfly; cash register; caveman; chatterbox; cheerleader; clockwork; clothespin; coffeepot; cornbread; countdown; cutting board; daredevil; dashboard; daybreak; doghouse; dogsled; dollhouse; doorknob; doorman; downpour; dump truck; dustpan; earthworm; eggplant; eyebrow; ferryboat; fireman; fireside; fishbone; flashlight; fortune teller; golf club; grandstand; gaveyard; handbook; hardship; hot dog; housewife; jump rope; lakeside; landlord; landmark; lawnmower; light bulb; lipstick; lookout; mailbox; manhole; milestone; motorcycle; mountain climber; mousetrap; oilcloth; outburst; outlaw; overcoat; palm tree; paper clip; piggy bank; pine cone; plywood; pogo stick; policeman; postcard; powerhouse; quicksilver; raincoat; rattlesnake; riverbank; rosebud; runoff; scarecrow; schoolbook; seacoast; seahorse; seaport; sewing machine; shortstop; skateboard; skyscraper; slowdown; snowdrift; snowfall; southpaw; spacecraft; spider web; spinning wheel; springboard; staircase; standpipe; starfish; steamship; stepmother; stoplight; takeoff; takeover; tape recorder; teakettle; thumbtack; toothpick; totem pole; touchdown; tow truck; typewriter; underbrush; videotape; warpath; washcloth; wastebasket; waterfall; watermelon; weather vane; wildfire; windbreak; windmill; woodpecker; woodwind; workroom