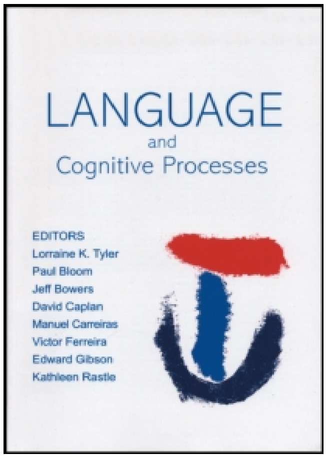

Language and Cognitive Processes
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713683153

Sublexical units and supralexical combinatorics in the processing of interfixed Dutch compounds

Andrea Krott [a]; Peter Hagoort [b]; Harald R. Baayen [c]
[a] University of Birmingham, Birmingham, UK.
[b] F.C. Donders Centre for Cognitive Neuroimaging, the Netherlands.
[c] University of Nijmegen, Nijmegen, the Netherlands.

Online Publication Date: 01 June 2004
To cite this Article: Krott, Andrea, Hagoort, Peter and Baayen, Harald R. (2004) 'Sublexical units and supralexical combinatorics in the processing of interfixed Dutch compounds', Language and Cognitive Processes, 19:3, 1
To link to this article: DOI: 10.1080/769813936
URL: http://dx.doi.org/10.1080/769813936

LANGUAGE AND COGNITIVE PROCESSES, 2004, *19* (3), 453–471

Sublexical units and supralexical combinatorics in the processing of interfixed Dutch compounds

Andrea Krott
University of Birmingham, Birmingham, UK

Peter Hagoort
F.C. Donders Centre for Cognitive Neuroimaging, the Netherlands

R. Harald Baayen
University of Nijmegen, Nijmegen, the Netherlands

This study addresses the supralexical inferential processes underlying wellformedness judgements and latencies for a specic sublexical unit that appears in Dutch compounds, the interfix. Production studies have shown that the selection of interfixes in novel Dutch compounds and the speed of this selection is primarily determined by the distribution of interfixes in existing compounds that share the left constituent with the target compound, i.e. the ‘‘left constituent family’’. In this paper, we consider the question whether constituent families also affect wellformedness decisions of novel as well as existing Dutch compounds in comprehension. We visually presented compounds containing interfixes that were either in line with the bias of the left constituent family or not. In the case of existing compounds, we also presented variants with replaced interfixes. As in production, the bias of the left constituent family emerged as a crucial predictor for both acceptance rates and response latencies. This result supports the hypothesis that, as in production, constituent families are (co-)activated in comprehension. We argue that this co-activation is part of a supralexical inferential process, and we discuss how our data might be interpreted within sublexical and supralexical theories of morphological processing.

Correspondence should be addressed to Andrea Krott, School of Psychology – Hills Building, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK. Email a.krott@bham.ac.uk

This study was financially supported by the Dutch National Research Council NWO (PIONIER grant to the third author), the University of Nijmegen (the Netherlands), and the Max Planck Institute for Psycholinguistics (Nijmegen, the Netherlands). We want to thank Dominiek Sandra and an anonymous reviewer for their comments on an earlier version of this paper.

http://www.tandf.co.uk/journals/pp/01690965.html DOI: 10.1080/01690960344000251

INTRODUCTION

This study investigates a specific kind of sublexical unit, the interfix, that occurs in compounds in a range of Germanic languages including German, Swedish, Danish, and Dutch. Dutch interfixes are enigmatic in several respects. First, the form of Dutch interfixes suggests that they might be suffixes. For instance, the interfix *-en-* in *boek-en-kast*, ‘‘book case’’, is similar to the plural *-en* in *boek-en*, ‘‘books’’, and Schreuder, Neijt, Van der Weide, and Baayen (1998) have shown that this interfix may elicit plural semantics for *boek* ‘‘book’’ in *boekenkast*. But in *pann-en-koek*, ‘‘pancake’’, the *-en-* does not contribute a plural meaning. While a bookcase is a case for books, a pancake is not a kind of food made in several pans. This example illustrates that, unlike normal affixes, the semantics of interfixes are underdetermined. Second, the distribution of the interfixes is underdetermined as well. A given noun may appear with no interfix at all in some compounds, and with interfixes in other compounds. For instance, *rund-vlees*, ‘‘beef’’ has no interfix, but *rund-er-gehakt*, ‘‘minced beef’’, contains the interfix *-er-*. There are no clear syntagmatic rules governing the distribution of the interfixes. To complicate matters, some words appear both with and without interfix. Thus, *spelling-regel* ‘‘spelling rule’’ coexists side by side with *spelling-s-regel*. Third, even though semantically and distributionally underdetermined, speakers of Dutch have clear intuitions about whether an interfix is appropriate for a given compound, and if so, which interfix is the preferred choice.

These enigmatic properties of interfixes raise the question of how interfixes are produced and understood. What guides a speaker of Dutch to say *asielzoeker-s-centrum* more often than *asielzoeker-centrum*? Why is it that to a Dutch reader or listener, *asielzoeker-s-centrum* intuitively feels somewhat more appropriate than the form without the interfix *-s-*?

A series of recent studies have addressed the production of interfixes. These studies have shown that the distribution of Dutch and German interfixes is primarily determined by paradigmatic analogy (Krott, Baayen, & Schreuder, 2001; Krott, Schreuder, & Baayen, 2002a, 2002b). The notion of paradigmatic analogy can be made precise in terms of the probability distributions of interfixation in the constituent families of the left and right constituents of a given compound. The left constituent family of a noun such as *boek-en-kast* consists of all compounds in Dutch that share the modifier *boek* as the left constituent. Similarly, the right constituent family of *boek-en-kast* is the set of compounds sharing the head *kast* as the right constituent. Lexical statistics, experimentation, and computational modelling all show that the probability distributions of interfixation in these constituent families, primarily the left constituent family, but also to some extent the right constituent family, guide the selection of the interfix in production. The greater the probabilistic support for an interfix given the left and right constituents, the more likely it is to be selected, and the shorter the time required to select the interfix is. Conversely, an interfix with little paradigmatic support is hardly ever selected, and when it is selected, selection times are long (Krott et al., 2002b). When the probability distributions of interfixation in the constituent families are uniform, i.e., all interfixation possibilities are equally plausible within a given constituent family, participants are unsure about what interfix to select, and the choices made are variable within and across speakers.

The observed effects of paradigmatic analogy can be understood as arising from activation spreading within the left and right constituent families. A computational model is formulated in Krott et al. (2002a). Reformulated within the general framework of Levelt, Roelofs, and Meyer (1999), the conceptualisation process would lead to the activation of the lemma of, e.g., *boek-en-kast* (''book case''). This lemma would in turn activate the lemmas of its constituents *boek* (''book''), *kast* (''case''), and that of the interfix *-en-*. When activation is allowed to spread from *boek* (strongly) and *kast* (weakly) to the lemmas of the compounds in their left and right constituent families, with these compounds in turn co-activating their own interfixes, the pattern of activation of the interfixes will come to reflect the weighted sum of the probability distributions of the left and right constituent families. Combined with a thresholding mechanism, the observed patterns of interfix selection and the corresponding selection latencies result, as shown by Krott et al. (2002a).

Thus far, the possible role of paradigmatic analogy for interfixes in language comprehension has not been studied. The present study addresses this issue for the visual modality. In order to understand how paradigmatic analogy might arise, it is useful to consider briefly the two main theories of morphological processing in visual word recognition.

According to ''sublexical'' theories of morphological processing, morphological structure is already detected during the early stages of visual processing, before lexically stored information is accessed. Sublexical effects, such as the longer rejection latencies obtained for Italian pseudo-affixed words by Burani, Dovetto, Thornton, and Laudanna (1997) or the equivalent effect of masked priming obtained by Longtin, Segui, and Hallé (2003) for French opaque derived words and pseudo-derived simplex words, can be accounted for by assuming that affixes are sublexical units with their own visual access representations. Frequency effects for complex words can be explained by assuming that complex words also have access representations with activation levels proportional to frequency of use (Sereno & Jongman, 1997; Baayen, Dijkstra, & Schreuder, 1997; Bertram, Laine, Baayen, Schreuder, & Hyönä, 1999).

According to ''supralexical'' theories, however, morphological structure does not leave traces at prelexical levels of processing (Giraudo & Grainger, 2001, 2003). Instead, morphological effects are constrained to occur after access to the lexicon has been completed. Frequency effects for compounds can be explained by assuming that co-occurrence probabilities are available for combinations of word constituents. Effects suggesting the presence of access representations for affixes have to be explained in terms of inferential processes generalising over stored lexical representations of affixed words.

In this study, we will remain agnostic as to whether morphology has a sublexical component. In what follows, we will build on the minimal assumptions that, upon visual presentation of a Dutch compound, (1) the modifier and head lemma representations will be activated, (2) that a lemma representation for the interfix will be activated, either through bottom-up activation from a dedicated access representation, or by an inferential lexical process, and (3) that in the case of existing words, the lemma representation for the compound will be activated, either through a corresponding access representation, or through lexical tracking of the co-occurrence likelihood of head and modifier.

These assumptions lead to a number of predictions. First, it follows from assumption (1) that the constituent families of the head and modifier might be activated during reading, thanks to activation spreading from the head and the modifier into their respective constituent families. Second, assumption (2) predicts that changing the interfix in existing words, and using different interfixes in novel compounds, should be detected and affect lexical processing. Third, given assumption (3), frequency effects for the compound as a whole are expected that might interact with changing the interfix in existing words.

Note that within this framework, paradigmatic analogy, if present, would arise as a purely supralexical effect. Consequently, the theoretical goal of the present paper can be viewed as showing how inferential processes of the kind required by supralexical theories of morphology might work in the case of the – sublexical – interfixes of Dutch.

There is one line of research suggesting that an effect of paradigmatic analogy may well be present in reading, namely, the work by Gagné and colleagues on the semantic interpretation of compounds (Gagné, 2001; Gagné & Shoben, 1997). These authors show that the interpretation of a compound is guided by the probability distribution of the semantic relations entertained by the modifier constituent. Given that paradigmatic analogy constrains and guides semantic interpretation, we expect paradigmatic analogy to likewise guide and constrain the interpretation of the interfixes.

Job No. 3976 MFK-Mendip Page: 457 of 471 Date: 13/5/04 Time: 6:27am Job ID: LANGUAGE SI-5

On the other hand, the possibility of an effect of paradigmatic analogy is called into question by the results reported by De Jong, Feldman, Schreuder, Pastizzo, and Baayen (2002) for Dutch compounds without interfixes. De Jong et al. manipulated the type count of both left and right constituent families, i.e., the morphological family size of the modifier and the head. The morphological family size has been shown to co-determine response latencies in lexical decision experiments for both monomorphemic words (e.g., De Jong, Schreuder, & Baayen, 2000; Schreuder & Baayen, 1997) and derived words (Bertram, Schreuder, & Baayen, 2000). Like the effect of the constituent family on the selection of interfixes, the effect of family size has been interpreted as indicating co-activation of family members during lexical processing (e.g., Schreuder & Baayen, 1997). De Jong et al. (2002) reported a facilitatory family size effect for both the modifier and the head. However, post-hoc analyses suggested that a correlated variable, the summed frequency of the compounds of the families sharing either the head or the modifier, is the crucial predictor. This suggests that the probability of a noun to be modifier or head in a compound might be the crucial predictor. While these findings support our assumption (1), namely, that the constituents of a compound are detected, it is unclear whether type-based analogical effects should be expected when moving from compounds without interfixes to compounds with interfixes.

In order to study the possible effect of paradigmatic analogy, we made use of a variant of the lexical decision task, namely, a wellformedness decision task. Instead of having to decide whether a letter string is a word of Dutch in a list containing both words and pseudo words, we asked participants to decide whether letter strings were well-formed words of Dutch in a list containing compounds with conventional and non-conventional interfixes and correct as well as incorrect plural suffixes. The use of wellformedness decision instead of lexical decision has several advantages. First, in lexical decision, the semantic interpretability of a compound co-determines response latencies. By directly tapping into grammaticality judgements, we hope to reduce semantic paradigmatic analogy as a source of variation in our experiment. Second, replacing the conventional interfix may result in a word that feels more grammatical, or in a word that feels less grammatical, depending on whether the change goes with or against the probabilistic bias. Since both the original form and the manipulated form are legitimate words of the language, lexicality decisions are inappropriate for the question at hand. Third, in order to study the reading of novel interfixed compounds, neologisms were included in the experiment. Such neologisms are likely to elicit no-responses in lexical decision, an understandable response that, however, is of no use for the understanding of paradigmatic analogy in comprehension of new possible Dutch words.

A disadvantage of the wellformedness decision task, that it shares to some extent with visual lexical decision, is that it is unclear to what extent strategic processes might be involved, and hence, to what extent it reflects normal reading of continuous text. Although wellformedness latencies are somewhat longer than lexical decision latencies, they are far too short for strategic effects involving the left and right constituent families—speakers of Dutch are completely unaware of why they find some interfixed compounds more acceptable than others. Further research using, e.g., eye-movement recordings, will have to clarify to what extent the effects obtained with this task in vitro generalise to reading in vivo.

In what follows, we therefore present a wellformedness decision experiment addressing the question of whether the analogical effect of the left constituent family that has been observed in production experiments can also be attested for wellformedness decisions of novel and existing Dutch compounds.

EXPERIMENT

To study the role of paradigmatic analogy in comprehension, we made use of an incomplete factorial design with three factors. The first factor of interest is the Existence of the compound (levels Existing and Novel). The critical manipulation, however, is the support for a given interfix provided by the bias of the left constituent family. The bias of the left constituent family with respect to a given interfix is the probabilistic support that this interfix receives. A positive bias indicates that the interfix is the maximum likelihood choice, a negative bias indicates that it is dispreferred. For this experiment, we defined two levels for the factor Left Bias: Support (the interfix is the maximum likelihood choice) versus No Support (there is little or no support for the interfix). We expect faster response latencies when the interfix is supported by the bias than when it is not supported. In case of novel compounds, we also expect participants to accept a compound more often as well-formed if its interfix is supported by the bias. In the case of existing compounds, a third variable comes into play: whether the interfix is the conventional choice in current use. Since existing compounds usually have a single conventional interfix, we can replace the conventional interfix by another, non-conventional one. This leads us to the third factor in our experiment, the factor Replacement with two levels, Normal and Replaced. We expect that participants rarely accept a replaced interfix since this leads to an unusual form of a known compound, and to find rejections even if a replaced interfix is supported by a large part of the constituent family. However, we expect that an interfix will be less often rejected if it is supported by the bias.

Method

Materials. We determined frequencies and constituent families for all compounds that we used in our experiment on the basis of the CELEX database (Baayen, Piepenbrock, & Gulikers, 1995). We first constructed a list of 160 novel compounds in the plural form (List 1) using interfixes that were supported by the Left Bias. Support by the Bias was quantified as the percentage of family members containing the interfix of the target compound. Across the items in our experiment, the mean percentage was 96.7% (range 70.6–100%). The mean number of such supporting compounds was 10.5 (range 1–78). An example of a compound with a Left Bias is *mosterdzielen* ''mustard souls''. (For ease of exposition, we will describe the absence of an overt interfix as the presence of a zero-interfix. Thus, *mosterd* is described as having a strong positive bias for the zero interfix.) The bias of the right constituent family for the chosen interfix varied, but was neutral on average (average bias: 45.1% (3.2 family members), range 0–95.5% (0–90 family members)). For each compound of List 1, we constructed three additional variants. List 1a contained compounds in which the interfix was replaced by an interfix that is not supported by the Left Bias (new left bias: mean 1.7% (0.2), range 0–29.4% (0–14)) new right bias: mean 31.1% (2.6), range 0–78.9% (0–22); example: *mosterdszielen* ''mustards souls''). The second and third variants (Lists 1b and 1c) mirrored Lists 1 and 1a with respect to the interfix, but used an ungrammatical plural suffix (*mosterdziels* ''mustard souls'', *mosterdsziels* ''mustards souls''). These words served as targets for an experiment not reported here, and served as fillers for the present experiment. For the sake of comparability with this other experiment, the target items for the present study were also presented in their plural form.

In addition, we selected two lists of existing compounds from the CELEX database: List 2 contained 160 compounds in the plural form with interfixes that were supported by the Left Bias (bias strength: mean 98.3% (23.1), range 80–100% (4–200); example: *filmtheaters* ''film theaters'' with a bias for the zero interfix), while List 3 contained plural compounds with interfixes that were not supported by the Left Bias (*vruchtbomen* ''fruit trees'' with bias for *-en-*). Since the latter type of compounds is rare, the size of List 3 was smaller (62 compounds, bias strength: mean 14.7% (2.4), range 0–29.4% (0–15)). The bias of the right constituents in both Lists 2 and 3 usually preferred the same interfix as the bias of the left constituents (List 2: bias strength: mean 56.5% (6.9), range 0–100% (0–46); List 3: bias strength: mean 27.1% (6.1), range 0–91.3% (0–52)). Thus, the right bias was in line with the left bias. For each compound of Lists 2 and 3, we constructed a variant (Lists 2a and 3a) by replacing the normal interfix with another one, such that for List 2 the new interfixes were not supported by the Left Bias (new left bias: mean 0.9% (0.2), range 0–20% (0–8); new right bias: mean 24.3% (3.1), range 0–77.8% (0–28); example: *filmen-theaters* ''films theaters''), while for List 3 the new interfixes were supported by the Left Bias (new left bias: mean 84.3% (15.7), range 70–100% (4–72); new right bias: mean 55.6% (11.8), range 0–100% (0–50)); *vruchtenbomen* ''fruits trees''). For the compounds of List 2 and List 2a, we again constructed the corresponding filler plural compounds with incorrect plural suffixes (*filmtheateren* ''film theaters''; *filmentheateren* ''films theaters''). We did not create a corresponding list for List 3 since this list is too small (62 compounds) to be split up into more than 2 groups for a between-subject design.

The compounds of Lists 1 to 3 were matched for length, the compounds of Lists 2 and 3 were also matched for frequency (List 1: length: mean 12.2 letters = 4.5 cm, range 3.2–5.4 cm; List 2: length: mean 12.0 letters = 4.5 cm, range 3.1–5.0 cm; compound frequency (per 42 million wordforms): mean 21.7, range 0–342; List 3: length: mean 12.5 letters = 4.4 cm, range 3.3–5.2 cm; compound frequency (per 42 million wordforms): mean 23.4, range 0–258).

We distributed the items over four experimental lists such that each experimental list contained a compound stem only once (abstracting away from plural suffix and interfix). This ensured that no participant saw a compound stem twice. Thus, a given participant was exposed to 160 novel compound stems (40 stems with support for interfix and correct suffix, 40 stems with support for interfix and incorrect suffix, 40 stems with unsupported interfix and correct suffix, and 40 stems with unsupported interfix and incorrect suffix), to 160 existing compounds with a strong left bias for the conventional interfix (40 stems with conventional interfix and correct suffix, 40 stems with conventional interfix and incorrect suffix, 40 stems with replaced interfix and correct suffix, and 40 stems with replaced interfix and incorrect suffix), to 62 compounds with no left bias for the conventional interfix (31 with the conventional interfix, and 31 with a non-conventional one). We also presented to each subject a set of 160 additional plural compounds with normal plural endings, which served the purpose of increasing the number of wellformed compounds (from 151 to 311), given the high number of illformed compounds for each subject (231). In all, a participant responded to 542 trials, preceded by 25 practice items.

Procedure. Participants were tested in a noise-attenuated experimental room. We asked them to decide as quickly and as accurately as possible

Job No. 3976 MFK-Mendip Page: 461 of 471 Date: 13/5/04 Time: 6:27am Job ID: LANGUAGE SI-5

whether a compound appearing on the screen is a wellformed Dutch compound, by pressing either a ‘‘yes’’ or a ‘‘no’’ button. We illustrated what they should treat as wellformed by means of an example of an existing compound. We presented an ‘‘illformed’’ (= replaced) interfix and an ‘‘illformed’’ (= replaced) suffix. We instructed them to treat existing and novel compounds equally, i.e., to judge the wellformedness, not the existence of the compound. Each trial started with a fixation mark remaining on the screen for 500 ms. After another 500 ms., the Dutch definite article for plural noun forms, *de* (Engl. ‘‘the’’), appeared on the screen and remained for 200 ms. The presentation of the article was inserted for the analysis of the fillers. For the present analysis, it has no other effect than being an additional fixation point. After another 200 ms, the stimulus compound appeared at the same position for 1500 ms. The maximum time span allowed for response was 2000 ms from stimulus onset of the compound. Stimuli were presented on Nec Multicolor monitors in white lowercase 21 point Helvetica letters on a dark background. The experiment was interrupted by three breaks and lasted approximately 40 mins.

Participants. Forty students of the University of Nijmegen were paid to participate in the experiment. All were native speakers of Dutch.

Results

Due to coding errors, we had to exclude from the analysis the responses to three existing compounds, two containing an interfix that was supported by the Left Bias, one containing an interfix that was not supported by the Left Bias. In addition, responses outside the maximum time span were counted as errors. Figure 1 and Table 1 summarise the mean percentages and the mean response latencies broken down by Left Bias and Existence. Note that in the case of existing compounds, the presented word either contained a normal or a replaced interfix and that the support by the Left Bias refers to the support of the interfix presented.

A by-item logistic regression analysis of the response decisions (wellformed or not wellformed) revealed signicant main effects of the Left Bias (more rejections when the interfix is not supported by the bias), $F(1, 756) = 639.0$, $p < .0001$, and Existence (more rejections for non-existing constituent combinations), $F(1, 757) = 35.6$, $p < .0001$, and no interaction between these factors, $F(1, 755) < 1$. Thus, existing compounds were accepted as being wellformed more often than novel compounds. More importantly, participants accepted a compound more often when the interfix was supported by the Left Bias than when it received no such support.

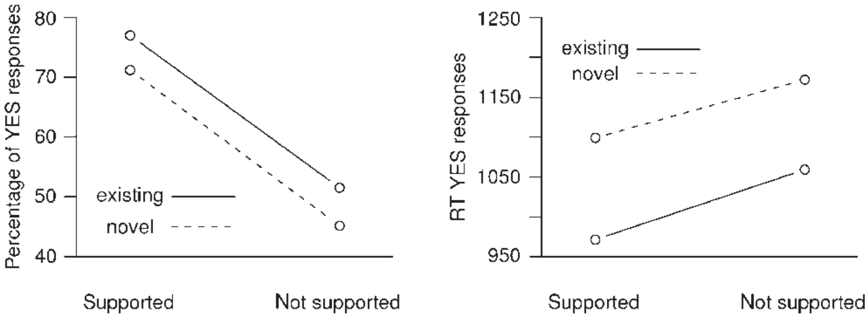

Figure 1. Mean percentage and mean response latency (RT in ms) of ''yes'' responses to existing and novel compounds with interfixes that are supported or not supported by the Left Constituent Family Bias.

Since we know from production studies that the bias of the right constituent family also has an effect on the decisions, we included it as a covariate. The covariance analysis supported the main effects of Left Bias, $F(1, 756) = 639.0, p < .0001$, and Existence, $F(1, 757) = 35.6, p < .0001$, and revealed an additional effect of the Right Bias (a higher acceptance rate as the support from the right constituent family increases), $F(1, 755) = 26.6, p < .0001$. None of the factors interacted with each other. We conclude that the wellformedness decisions are based not only on the bias of the left constituent family, but also on the right constituent family, just as observed previously for the production of interfixes.

We also examined the counts of wellformedness decisions for the novel compounds and the existing compounds separately, as this allows us to

TABLE 1

Percentage of yes responses, no responses, and errors as well as mean response latencies (RT in ms, standard deviations in parentheses) when deciding on the wellformedness of novel (3200 responses) and existing compounds (5620 responses) containing interfixes that are supported by the Left Constituent Family Bias versus interfixes that are not supported by the Left Constituent Family Bias

		Supported		*Not supported*	
Compound type	*Response*	%	*RT*	%	*RT*
existing	yes	77.0	971 (275)	51.5	1059 (304)
existing	no	20.6	1121 (280)	45.5	1131 (267)
existing	error	2.4		3.0	
novel	yes	71.2	1099 (284)	45.1	1172 (291)
novel	no	27.0	1216 (301)	51.9	1175 (303)
novel	error	1.8		3.0	

include various frequency measures as covariates, including the frequency of the compound as a whole (available only for the existing compounds) and the frequency of the constituents as independent nouns.

First consider the novel compounds. The bottom half of Table 1 and Figure 1 summarise the pattern of results broken down by Left Bias. A logistic analysis of covariance revealed a main effect of Left Bias (no support by Left Bias implies more rejections), $F(1, 318) = 222.37$, $p < .0001$, and an interaction of Right Bias and the frequency of the right constituent as an independent noun (a greater Right Bias combined with a greater right frequency leads to a higher acceptance rate), $F(1, 317) = 26.18$, $p < .0001$.

Next consider the existing compounds. Table 2 and Figure 2 show the cell means broken down by Replacement and Left Bias. A logistic analysis of covariance revealed main effects of Replacement (replacing the conventional interfix led to more rejections), $F(1, 438) = 614.62$, $p < .0001$, and Left Bias (support by the bias led to fewer rejections), $F(1, 437) = 335.78$, $p < .0001$, as well as three interactions. The interaction of Replacement by Compound Frequency showed that a higher frequency led to higher acceptance rates for compounds with the conventional interfix, and to higher rejection rates for compounds with a non-conventional interfix, $F(2, 435) = 36.33$, $p < .0001$, as expected. The interaction of Right Bias by the Right Constituent Family Frequency shows that a high right bias combined with a head constituent that is very frequent as a head in compounds led to higher acceptance rates, $F(1, 432) = 11.66$, $p = .0006$. This suggests a cumulative effect of the lexicality of the head on the wellformedness of the interfix. The third interaction, Replacement by Right Bias, is enigmatic, as it suggests that a greater Right Bias led to more

TABLE 2

Percentage of yes responses, no responses, and errors as well as mean response latencies (RT in ms, standard deviations in parentheses) when deciding on the wellformedness of existing compounds with normal and replaced interfixes that are either supported by the Left Constituent Family Bias or not supported by the Left Constituent Bias

		Supported		*Not supported*	
Interfix	*Response*	%	*RT*	%	*RT*
normal	yes	83.9	967 (273)	73.7	1023 (294)
normal	no	14.1	1120 (288)	23.1	1162 (270)
normal	errors	2.0		3.2	
replaced	yes	68.1	977 (278)	34.4	1119 (312)
replaced	no	29.0	1121 (277)	63.0	1122 (266)
replaced	errors	2.6		2.9	

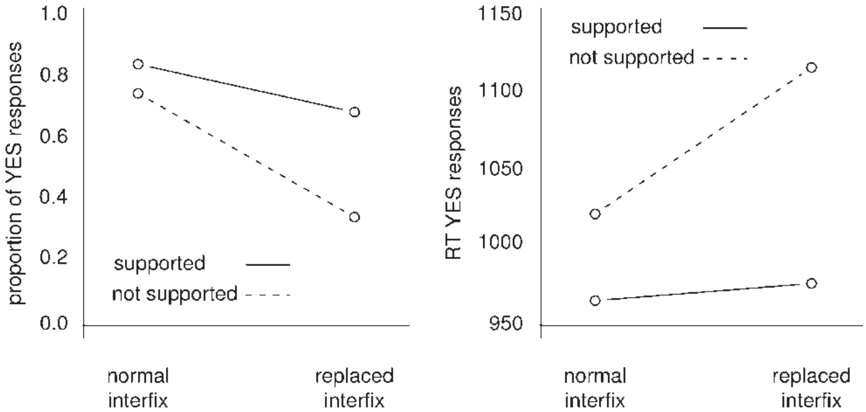

Figure 2. Proportion and response latencies (RT in ms) of yes responses to existing compounds with normal and replaced interfixes that are either supported or not supported by the Left Constituent Family Bias.

rejections for the compounds with the conventional interfix, $F(2, 433) = 10.61$, $p < .0001$, instead of less rejections.

The results for replaced interfixes are remarkable. We expected that participants would rarely accept a replaced interfix since a replacement leads to an unusual form of the compound. This expectation turned out to be wrong. Compounds containing replaced interfixes were accepted very often when the replaced interfix was supported by the Left Bias (844 out of 1240 compounds). In other words, when the conventional interfix is exceptional given the probability distribution of the interfixes in the left constituent family, our replacement manipulation amounted to a form of regularisation that made the compound more wellformed.

Considered jointly, these analyses document the importance of the left and right bias for wellformedness decisions for novel and existing compounds. The combined presence of frequency effects of the compound as a whole and of its constituents provide further support for the (supra)lexical basis of the wellformedness decisions, as expected given our spreading activation model developed for the production of interfixes.

We now turn to consider the decision latencies in our experiment. A multi-level analysis of covariance with log response latency as dependent variable, and Existence, Left Bias and type of Response (positive versus negative wellformedness judgements) as predictor variables, with Right Bias as covariate, and with Subject as error stratum (see, e.g., Pinheiro & Bates, 2000) revealed main effects for Left Bias, Right Bias, and Response, as well as various interactions between these variables and Existence (all p values less than .02). We therefore analysed the yes and no responses separately for the subsets of novel and existing compounds.

First consider the response latencies for the novel compounds judged to be wellformed. We carried out a multi-level analysis of covariance with log response latency as dependent variable, Left Bias as predicting factor, and various frequency measures pertaining to the two constituents of the compound as covariates. (The logarithmic transformation of the response latencies changes a skewed, non-normal distribution into a nearly normal distribution, thereby bringing the dependent variable more in line with the normality assumptions of linear modelling and analysis of variance.) Of these measures, the frequency of the right constituent, as well as the family frequency of the right constituent, turned out to be relevant. After stepwise removal of irrelevant predictors, we observed a main effect for the frequency of the right constituent (compounds with a higher-frequency right constituent were responded to faster, $t(1819) = -2.39$, $p = .0169$), as well as two interactions, one of the frequency of the right constituent by Left Bias (compounds with an interfix not supported by the Left Bias were responded to more slowly for increasing frequency of the right constituent, $t(1819) = 6.12$, $p < .0001$), and one of the Right Bias by the Right Constituent Family Frequency (a higher Right Bias combined with a higher Right Constituent Family Frequency led to faster response latencies, $t(1819) = -5.12$; $p < .0001$). These main effects and interactions all remained highly significant in a sequential analysis of variance. (This also holds for all analyses to follow below.) The standard deviation of the Subject random effect was estimated at 0.1651, and that of the residual error at 0.2111. In sum: higher frequency counts for the right constituent led to faster positive responses for novel compounds, except when there is a conflict between an interfix not supported by the Left Bias (requiring a no-response) and a high right constituent frequency (requiring a yes-response). The latter suggests that the Right Bias might only influence response times when the compounds of the right family have sufficiently strong representations. Note that there was no independent contribution of the Left Bias to the response times. The large difference in Table 1 is due to the interaction of Left Bias and frequency of the right constituent. Assuming that left constituents are processed before right constituents, the strong effects of frequency measures of the right constituent might have masked any effects of the left constituent.

A similar analysis was carried out for the response latencies of the novel compounds judged to be not well-formed. For this subset of trials, we observed a main effect of Left Bias (lack of Left Bias support led to shorter rejection latencies, $t(1221) = -2.40$, $p = .0165$), as well as a main effect of Right Bias (a greater Right Bias led to faster rejection latencies, $t(1221) = -2.20$, $p = .0278$). Interestingly, the interaction between Left and Right Bias, $t(1221) = 2.8655$, $p = .0042$, showed that for compounds with an interfix not supported by the Left Bias, the effect of Right Bias was inhibitory. In other words, novel compounds with an interfix that is not supported by the Left Bias are easy to reject, except when there is a conflict with the Right Bias. The standard deviation of the subject random effect was 0.1343, and that of the residual error 0.2211.

Turning to the analysis of response latencies of existing compounds, we first consider the positive responses. We studied two factors, Replacement (is the interfix the conventional one or not), and Left Bias (is the interfix supported by the Left Bias or not). Covariates that turned out to be important in this analysis were Right Bias, Right Constituent Family Frequency, Compound Frequency, and the frequency of the left constituent. Main effects were observed for Left Bias [response latencies are longer when the Left Bias is small, $t(3604) = 2.09$, $p = .0365$], the Right Bias [a higher right bias led to longer response latencies, $t(3604) = 3.36$, $p = .0008$], and Compound Frequency [higher-frequency compounds are accepted faster, $t(3604) = -10.40$, $p < .0001$]. In addition, there were three interactions: an interaction between Replacement and Left Bias showed that a replaced interfix led to slower responses when there was no support of the Left Bias, $t(3604) = 5.63$, $p < .0001$. Note that a replaced interfix with a high Left Bias was accepted as fast as a conventional interfix with high Left Bias. An interaction between Right Bias and Right constituent family frequency indicated that for right constituents with non-negligible right family frequency, the right bias is facilitatory, $t(3604) = -5.79$, $p < .0001$. Finally, we observed an interaction between left constituent frequency and right constituent family frequency [compounds with left constituents that are frequent nouns and right constituents that occur in compounds that are frequent have shorter responses, $t(3604) = 4.75$, $p < .0001$]. Thus, for existing compounds, various measures of frequency of occurrence, the Left and Right Bias as well as Replacement of the interfix emerge as crucial determinants of response speed. The standard deviations of the subject random effect and the residual error were 0.1591 and 0.2306 respectively for the fitted multilevel model.

Finally, we consider the rejection latencies for the existing compounds. The only main effects for this subset of the data were Right Bias [a higher right bias led to shorter response latencies, $t(1838) = -3.79$, $p = .0002$] and Compound Frequency [higher frequency compounds were rejected faster, $t(1838) = -4.38$, $p = .0001$]. There was a significant interaction between Right constituent family frequency and Left constituent frequency [compounds with left constituents that are frequent nouns and right constituents that occur in compounds that are frequent elicited shorter responses, $t(1838) = 2.64$, $p = .0084$]. The prominent role of frequency suggests that the non-conventional use of an interfix is more easy to detect in higher frequency compounds and in compounds with more frequent constituents. For the multilevel model fit to this subset of the data, the standard deviation of the subject random effect was approximately 0.1099, and that of the error 0.2090.

DISCUSSION

This study addressed the supralexical combinatorics underlying perceived wellformedness of a particular sublexical unit, the interfix in Dutch compounds. All experimental research carried out thus far on interfixes has studied the production of interfixes in novel compounds. This study addresses the perceived wellformedness of interfixes, broadening the scope from production to comprehension, and studying not only novel compounds, but also existing compounds. We made use of a well-formedness decision task requiring participants to indicate, by means of a button box, as quickly and accurately as possible, whether a visually presented compound was a well-formed word of Dutch. We analysed both the wellformedness decisions themselves and the time (in ms) required to reach these decisions. The main pattern in the data is that, as in the production of interfixes, the probability distribution of interfixation in the left constituent family of a compound is a crucial predictor of both wellformedness decisions and of the corresponding response latencies. A stronger bias, i.e., stronger probabilistic support, leads to a higher incidence of positive wellformedness decisions and to shorter response latencies.

The pattern of results for the existing compounds is especially revealing. For these compounds, we observed a strong effect of compound frequency. Not surprisingly, a greater familiarity with a compound gives rise to more positive wellformedness decisions and to reduced response latencies. Replacement of the conventional interfix in a compound by another interfix was detected more often for higher-frequency compounds, and led to a reduction in the number of positive decisions, as expected. Interestingly, a strong left bias led to more positive wellformedness decisions, and to shorter response latencies, independently of the frequency of the compound, and also independently of whether the interfix in the compound was the conventional one or an experimental replacement. Although replacing the interfix by a non-conventional interfix led to lower acceptance rates, it reduced the speed of acceptance only if the interfix was not supported by the left bias. This shows that the processing of existing compounds is not merely a matter of activating the lemma of the compound. If that were the case, no effect of the left bias would be present, contrary to fact. Apparently, the left bias is effective ‘‘on-line’’, independently of whether the compound exists or not, supporting congruent interfixes and exerting regularisation pressure on incongruent interfixes.

Our experimental work on the production of interfixes revealed a small but consistent effect of the bias of the right constituent family in addition to the strong effect of the left constituent family (e.g., Krott et al., 2002a). The present comprehension experiment also revealed such an effect for the right bias, sometimes as a main effect, but often in interaction with other frequency measures such as the right constituent family frequency. Like the left bias, a right bias supporting the interfix leads to more positive decisions and to shorter response latencies.

In this study, we included various frequency measures as covariates that have been reported in the literature as affecting visual lexical processing, such as the frequencies and the positional family frequencies of the left and right constituent families. Of special interest is the finding that in many of our analyses the positional family frequency of the right constituent emerged as a significant predictor. This statistic was first observed to be relevant for visual lexical processing by De Jong et al. (2002). However, while these authors observed a positional family frequency effect for both the right and the left constituent, we see such an effect only for the right constituent. We suspect this is due to the presence of compounds with incorrect plural endings in our filler materials, attracting attention to the right side of compounds, and due to the presence of nonword compounds with an existing left (or right) constituent in the materials of De Jong et al., spreading attention equally over both constituents.

Considered jointly, our results provide strong evidence for a supralexical inferential process underlying intuitions of the wellformedness of Dutch compounds. Krott et al. (2002a) documented the feasibility of such a supralexical inferential process by means of a simulation study for the production of interfixes in novel compounds. The present results suggest that a similar spreading activation model might be appropriate for comprehension.

First consider novel compounds. Upon presentation of a novel compound, the access representations of its head and modifier constituents are activated, which in turn activate their corresponding lemma representations. Subsequently, activation flows into the constituent families, leading to co-activation of the compounds in these constituent families. The co-activated compounds in turn provide support for the different interfixes, resulting in a distribution of lemma activation levels for the interfixes that mirrors the probability distribution of the interfixes in the constituent families.

In sublexical theories of morphological processing, an access representation for the interfix would also be activated, which in turn would activate a corresponding lemma representation. The percept of wellformedness of the compound would then depend on the degree of convergence or divergence between the bottom-up support and the inferential lexical

Job No. 3976 MFK-Mendip Page: 469 of 471 Date: 13/5/04 Time: 6:27am Job ID: LANGUAGE SI-5

support from the constituent families. In supralexical theories of morphological processing, no access representations for sublexical units such as interfixes are permitted. In order to explain the dependence of wellformedness on the Left Bias of the interfix in novel compounds, some mechanism is required that allows the form of the presented compound to be checked against the form of the compound that would be synthesised for production. The most likely representational level for such a comparison would be the level of phonological form. The degree of mismatch between the phonological form that arises from bottom-up visual processes and the synthesised phonological form that arises from inferential analogical processes would then determine the percept of wellformedness.

For exisiting compounds, the sublexical and supralexical explanations would proceed along similar lines, with the addition of a lemma representation for the compound itself enhancing the bottom-up support proportional to its frequency.

Given that the current experimental literature is ambiguous as to whether the sublexical or the supralexical account is to be preferred (compare, e.g., Longtin et al., 2003, with Giraudo & Grainger, 2001, 2003), and given that the present experiment documents supralexical aspects of comprehension but has nothing to say about possible sublexical effects of interfixes, we will remain agnostic as to which account is to be preferred.

In the present study, as in the preceding studies, the bias of the constituent families is based on a type count of the compounds in these constituent families supporting the interfixes of Dutch. We saw in several of our analyses that right family frequencies also influence decisions and response latencies. This raises the question of whether the probabilistic support for the interfixes should not be weighted by the frequencies of the compounds in the constituent families. The weight of a single high-frequency, well-known compound in the constituent family might be stronger than the combined contribution of several less-frequent compounds. Along the lines of the traditional concept of analogy found in linguistics, such a single influential exemplar might drive analogical inference (e.g., Anshen & Aronoff, 1988). As a first step towards a more refined probability measure, we therefore included the frequency of the compound with the highest frequency in the left constituent family as a predictor. A multi-level analysis of covariance revealed this frequency measure to be an additional significant predictor ($p < .0001$): the higher this maximum frequency, the higher the wellformedness. The fact that this maximum frequency measure does not render the bias superfluous as a predictor shows that the traditional linguistic concept of analogy is too restricted. On the other hand, the fact that it is a significant predictor shows that a principled way of weighting by token frequency needs to be developed.

Summing up, we conclude that the analogical sets of the left and right constituent families are highly involved in wellformedness decisions of novel and existing Dutch compounds. Our study has thus broadened the evidence for an effect of the constituent family from the domain of language production to the domain of visual lexical processing. There are two lines of research that are required to strengthen these results. First, it will be necessary to clarify whether and to what extent analogical inferential processes take place when we move from wellformedness decisions on isolated compounds to the reading of compounds in running text. Second, further research is required on the nature of the probability distributions in the constituent families, which thus far have been calculated on a type basis but for which weighting by token frequencies is clearly required.

REFERENCES

Anshen, F., & Aronoff, M. (1988). Producing morphologically complex words. *Linguistics*, *26*, 641–655.

Baayen, R.H., Dijkstra, T., & Schreuder, R. (1997). Singulars and plurals in Dutch: Evidence for a parallel dual route model. *Journal of Memory and Language*, *36*, 94–117.

Baayen, R.H., Piepenbrock, R., & Gulikers, L. (1995). *The CELEX lexical database* [CD-ROM]. Philadelphia, PA: Linguistic Data Consortium, University of Pennsylvania.

Bertram, R., Laine, M., Baayen, R.H., Schreuder, R., & Hyönä, J. (1999). Affixal homonymy triggers full-form storage even with inflected words, even in a morphologically rich language. *Cognition*, *74*, B13–B25.

Bertram, R., Schreuder, R., & Baayen, R.H. (2000). The balance of storage and computation in morphological processing: The role of word formation type, affixal homonymy, and productivity. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*, 419–511.

Burani, C., Dovetto, M., Thornton, A.M., & Laudanna, A. (1997). Accessing and naming suffixed pseudo-words. In G.E. Booij & J. Van Marle (Eds.), *Yearbook of morphology 1996* (pp. 55–73). Dordrecht: Kluwer.

De Jong, N.H., Feldman, L.B., Schreuder, R., Pastizzo, M., & Baayen, R.H. (2002). The processing and representation of Dutch and English compounds: Peripheral morphological, and central orthographic effects. *Brain and Language*, *81*(1/2/3), 555–567.

De Jong, N.H., Schreuder, R., & Baayen, R.H. (2000). The morphological family size effect and morphology. *Language and Cognitive Processes*, *15*, 329–365.

Gagné, C. (2001). Relation and lexical priming during the interpretation of noun-noun combinations. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *27*, 236–254.

Gagné, C., & Shoben, E.J. (1997). The influence of thematic relations on the comprehension of modifier-noun combinations. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*, 71–87.

Giraudo, H., & Grainger, J. (2001). Priming complex words: Evidence for supralexical representation of morphology. *Psychonomic Bulletin and Review*, *8*, 127–131.

Giraudo, H., & Grainger, J. (2003). On the role of derivational affixes in recognizing complex words: Evidence from masked priming. In R. Baayen & R. Schreuder (Eds.), *Morphological structure in language processing* (pp. 211–234). Berlin: Mouton.

Krott, A., Baayen, R.H., & Schreuder, R. (2001). Analogy in morphology: Modeling the choice of linking morphemes in Dutch. *Linguistics*, *39*(1), 51–93.

Krott, A., Schreuder, R., & Baayen, R.H. (2002a). Linking elements in Dutch noun-noun compounds: constituent families as predictors for response latencies. *Brain and Language*, *81*(1–3). 708–722.

Krott, A., Schreuder, R., & Baayen, R.H. (2002b). Analogical hierarchy: Exemplar-based modeling of linkers in Dutch noun-noun compounds. In R. Skousen, D. Londsdale, & D.B. Parkinson (Eds.), *Analogical modeling: An exemplar-based approach to language* (pp. 181–206). Amsterdam: John Benjamins.

Levelt, W.J.M., Roelofs, A., & Meyer, A.S. (1999). A theory of lexical access in speech production, *Behavioral and Brain Sciences*, *22*, 1–38.

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

Pinheiro, J.C., & Bates, D.M. (2000). *Mixed-effects models in S and S-PLUS*, Statistics and Computing. New York: Springer.

Schreuder, R., & Baayen, R.H. (1997). How complex simplex words can be. *Journal of Memory and Language*, *37*, 118–139.

Schreuder, R., Neijt, A., Van der Weide, F., & Baayen, R.H. (1998). Regular plurals in Dutch compounds: linking graphemes or morphemes? *Language and Cognitive Processes*, *13*, 551–573.

Sereno, J., & Jongman, A. (1997). Processing of English inflectional morphology. *Memory and Cognition*, *25*, 425–437.