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Frequency effects in noun phrase production: Implications for models of lexical access

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We investigated the processes of lexical retrieval during the production of adjectival noun phrases (NPs) such as "the blue kite". We used various current assumptions about the scope of grammatical and phonological encoding and about the locus of the classic frequency effect to derive predictions about possible frequency effects in the NP naming task. The predictions were tested in two picture-naming experiments where we manipulated orthogonally the frequencies of the adjective and of the noun that composed the NPs. We consistently found frequency effects for both adjectives and nouns. Moreover the effects were additive. We argue that the existence of a frequency effect for the noun during noun phrase production restricts the various combinations of assumptions that speech production models can hold simultaneously. Possible implications of the additivity of the effects for the time course of lexical access are also discussed.

The study of the mechanisms and representations involved in speech production has mainly focused on single word retrieval. Much less is known about the production of multi-word utterances. In order to produce this type of utterance the speech production system needs to retrieve several lexical units and to organise them into a well-formed utterance. According to current models of speech production (e.g., Levelt, Roelofs, & Meyer, 1999), the linguistic mechanisms involved in this process can be divided in three main components: grammatical, phonological, and phonetic encoding. In this article we address some issues about the organisation of these components. We report two picture naming

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experiments where participants had to name pictures by using adjectival noun phrases (NPs) of the form determiner + adjective + noun (e.g., "the blue kite"). Specifically, we explore the effects of the frequency of both the adjective and the nouns included in the NP, in order to shed some light on the planning units involved in speech production. NPs are simple utterances that can be easily elicited in classic picture-naming experiments; yet the production of an NP requires the kind of multi-word encoding we are interested in.

In the experiments reported here, the main experimental manipulation concerned the frequency of the items that compose the NP. We explore whether or not a difference in the frequency of the noun or in the frequency of the adjective will affect the speed with which the NP is produced. For example, we compared participants' performance in naming NPs such as "the blue kite" when they were composed of low frequency nouns like "kite" or high frequency nouns like "car", and of low frequency adjectives like "pink" or high frequency adjectives like "blue". As we argue below, the presence or absence of a frequency effect in the production of NPs can give us valuable information for a better understanding of the dynamics and the representations that are involved in the speech production process.

During the so-called grammatical encoding stage the speaker has to retrieve from the lexicon the lexical nodes that convey the meaning that she wants to communicate, and assign them to a syntactic frame in which the relationships among those words are specified (e.g., Bock & Levelt, 1994). During phonological encoding the phonological representations of the previously selected words are retrieved and combined according to phonological rules (e.g., Meyer, 2000). Finally, during phonetic encoding, the articulatory programmes of the phonological units computed in the preceding stage are retrieved and articulation starts. Another important aspect of current models of speech production is the assumption that the mechanisms involved in speech generation work incrementally: different parts of the utterance can be processed concurrently at the different levels outlined above. In other words, the speaker does not need to compute the whole utterance at one level of representation before its end-product can be delivered to the next stage of processing (for example, the phonological system may start retrieving the information corresponding to the first words of the utterance while the grammatical encoder is computing later parts). Nevertheless, it is assumed that there is some minimal amount of information that needs to be assembled at any level of representation before processing at the next level is triggered (e.g., Bock & Levelt, 1994; Ferreira & Swets, in press; but see Schriefers & Teruel, 1999).

One way to explore the planning units, or scope of processing, involved at each level of representation is to manipulate the lexical properties of the items involved in multi-word utterances (e.g., Costa & Caramazza, in press; Meyer, 1996; Schriefers & Teruel, 1999). This is because whether or not the manipulation of a given property can affect naming latencies will depend (a) on the processing level at which the effect of that property occurs, and (b) on how many items are processed concurrently at that level before speech is initiated. For example, if the scope of processing at a given level of representation includes the noun of an NP, then a manipulation that affects how fast the noun is processed at that level should produce an effect on naming latencies.

Here we make use of a property that has been shown to affect picture naming latencies: the frequency of the pictures' name. In a seminal study. Oldfield and Wingfield (1965) found that pictures with low frequency names are named slower than those with high frequency names. This so-called frequency effect has been shown to be a replicable and robust effect (e.g., Griffin & Bock, 1998; Jescheniak & Levelt, 1994; Levelt, Praamstra, Meyer, & Salmelin, 1998). Because the frequency effect is relatively independent of conceptual and visual factors and because it is not found or is very much reduced when a non-verbal response is required (Meyer, Sleinderink, & Levelt, 1998; Wingfield, 1968) it has been assumed that the locus of the effect is at some stage of lexical access (but see also Kroll & Potter, 1984). Converging evidence that frequency plays a role at some stage of word production comes from the study of aphasic patients. Some aphasic speakers show more difficulties in naming pictures with low frequency names than pictures with high frequency names despite normal access to the semantic representations of the depicted objects (e.g., Caramazza & Hillis, 1990).

Not all researchers agree that the variable "word frequency" is the causal factor underlying the frequency effect observed in picture-naming tasks. A number of researchers have proposed that the effects attributed to the variable word frequency might be due to a highly correlated, yet distinct, variable: the age at which the words are acquired (Barry, Morrison, & Ellis, 1997; Carroll & White, 1973b; Ellis & Morrison, 1998). In this report we will not address the issue of whether putative word frequency effects are in fact age of acquisition (AoA) effects. In our experiments these two variables are confounded and therefore indistinguishable. Nevertheless, we will refer to the manipulated variable as "word frequency" since explicit claims have been made about the locus of the frequency effect in the models of speech production we will consider here (Dell, 1990; Griffin & Bock, 1999; Jescheniak & Levelt, 1994; Levelt et al., 1999). However, this is not intended to prejudge the issue of whether AoA or word frequency best accounts for the putative frequency effects in picture naming: given our current understanding of the two variables either one could be used to account for the so-called frequency effects.

The frequency effect has been obtained in picture naming tasks in which subjects produce bare nouns. Will similar effects be observed when the task involves the production of an NP? An answer to this question depends on the assumptions we make about the locus of the frequency effect in lexical access and about properties of the NP production process. Of particular relevance here are the assumptions concerning the scope of processing at each level of representation in NP production.

For example, if one were to assume that frequency affects the retrieval of lexical nodes which are inserted into a grammatical frame (e.g., Dell, 1990) then the possibility of observing a frequency effect in NP production will depend on the scope of grammatical encoding. It could be that grammatical encoding encompasses units as large as the grammatical phrase, such that the whole NP falls in its scope. In this case, all the items that compose the phrase will be processed at the grammatical level before the information is sent to the next level of processing. Therefore, any manipulation which affects the ease with which the lexical items of the NP are retrieved will have an impact on when processing can start at the next level. A difference in the frequency values of the nouns of the NP would then be expected to affect naming latencies: NPs with low frequency nouns like "the blue kite" should be named slower than NPs with high frequency nouns like "the blue car".

Alternatively, one could assume that the frequency effect is located at the retrieval of the phonological properties of the words (Jescheniak & Levelt, 1994; Levelt et al., 1999) and this would lead to different predictions. Now the likelihood of observing a frequency effect during NP production will depend on the scope of phonological encoding. Various accounts of phonological processing invoke the existence of a unit of encoding that comprises a content word plus the function words that "attach" to it – the phonological word (Ferreira, 1993; Ferreira & Swets, in press; Lahiri, 2000; Levelt, 1989; Levelt et al., 1999; Selkirk, 1984; Wheeldon & Lahiri, 1997; see also Nespor & Vogel, 1986, for a definition of phonological words in terms of stress values). The notion of phonological word is relevant here because the noun of the adjectival NPs corresponds to the second phonological word (e.g., "the blue kite" = [the blue][kite], where square brackets delimit phonological words). Thus, if the scope of phonological encoding encompasses more than one phonological word then this scope would include all the items of an adjectival NP. Using the same logic that was applied earlier to grammatical encoding, this assumption also predicts an effect of the frequency of the noun. If, however, the scope of phonological encoding is only one phonological word, then the system will send the phonological information corresponding to the adjective (and the determiner) to the next stage of processing (e.g., phonetic/articulatory levels) as soon as its phonological encoding has been completed, without any requirement about the selection of the second phonological word (the noun in this example; Levelt, 1989; Wheeldon & Lahiri, 1997). The *phonetic* encoding of the first phonological word (determiner + adjective) would then be concurrent with the *phonological* encoding of the second phonological word (noun). In this case, NP naming latencies would not depend on the ease of retrieval of the phonological properties of the noun. They would only depend on the ease with which the first phonological word is encoded. Therefore, frequency effects for the noun should not be observed.[1]

Thus the different assumptions regarding the locus of the frequency effect and the dynamics of lexical access make different predictions about whether or not a frequency effect will be observed during the production of adjectival NPs. Interestingly, there have been contrasting claims about the locus of the frequency effect and about the scope of processing during NP production. Some authors locate the frequency effect at the level of lexical selection for grammatical encoding (e.g., Dell, 1990) while others argue that the effect is located at the level of phonological encoding (e.g., Jescheniak & Levelt, 1994; Levelt et al., 1999).

Furthermore, although there is converging evidence indicating that the scope of processing at the grammatical level encompasses a phrase, there is not nearly as much agreement concerning the scope of phonological encoding. The conclusion about the scope of grammatical encoding is motivated by various lines of evidence. These include the analysis of pauses and speech errors in spontaneous speech (e.g., Ford, 1982; Garrett, 1975), as well as evidence from reaction time experiments involving the production of simple utterances (e.g., Meyer, 1996; Schriefers, de Ruiter, & Steigerwald, 1999; Smith & Wheeldon, 1999; see also Smith, 2000). As an example of the latter type of evidence, consider a study by Meyer (1996) in which she asked participants to name pictures either with conjoined NPs (“the arrow and the bag”) or with simple sentences (“the arrow is next to the bag”) in a picture-word interference paradigm. She found that a delay in the retrieval of the first or the second noun of these utterances, due to semantic interference from a distractor word, both affected naming latencies. This result was interpreted as an indication that both the first noun (“arrow”) and the second noun of the utterance (“bag”) are concurrently active during grammatical encoding. Using a similar paradigm, Costa and Caramazza (in press) found that naming latencies for English NPs (determiner + adjective + noun) or Spanish NPs

[1] An implicit assumption that is made here is that the ease of processing of the noun at the phonological level does not affect the processing of the adjective at the phonetic/articulatory level. That is, the different levels have different processing resources. We will not discuss here the possibility that the two levels affect each other (a discussion of this issue can be found in Costa and Caramazza, in press).

(determiner + noun + adjective) were affected by the ease with which the noun and adjective lexical nodes were retrieved for both languages. All these results point to the conclusion that the scope of grammatical encoding encompasses a unit that is at least as large as an adjectival NP.

As already noted, the results regarding the scope of phonological encoding are less clear cut. There are basically two sets of results. The first set suggests that the level of activation of the phonological properties of the lexical nodes that fall outside the first phonological word does not affect naming latencies. In the same series of picture-word interference experiments cited above, Meyer (1996) found phonological facilitation effects for the first noun of the utterances but not for the second noun (see also Dell & O'Seaghdha, 1992). Similarly, Schriefers and Teruel (1999) found phonological facilitation effects for the adjective in adjective + noun NPs but not for the noun[2] (see also Schriefers et al., 1999). Both sets of results are consistent with the idea that the scope of phonological encoding encompasses no more than one or two words – that is, one phonological word (see also Wheeldon & Lahiri, 1997). Other evidence, however, suggests that the phonological processing of lexical items outside the first phonological word might in fact affect naming latencies. For example, in various picture word-interference experiments Costa and Caramazza (in press) found phonological effects for the third member of English (determiner + adjective + noun) and Spanish (determiner + noun + adjective) NPs. Notice that in both languages the third member of the utterance is in the second phonological word (e.g., [the red][car] or [el coche][rojo]). Evidence for the concurrent phonological processing of the adjective and the noun during the production of adjectival NPs also comes from studies of the selection of determiners in Romance languages (Alario & Caramazza, in press; Miozzo & Caramazza, 1999). In these experiments, the ease of selection of determiners was modulated by the phonological properties of both the noun and the adjective. A detailed discussion of the origin of the discrepancies between the studies that seem to favour the phonological word as the minimum unit of encoding and those that favour a broader unit can be found in Costa and Caramazza (in press), and Wheeldon (2000).

In short then, there are alternative views on the locus of the frequency effect in lexical access and on the size of the scope of phonological encoding. Different combinations of the assumptions about the locus of the frequency effect in lexical access and the scope of grammatical and

[2] These authors found phonological facilitation only for the first syllable of disyllabic adjectives. They interpreted the result as indicating that the unit of phonological encoding may even be smaller than one phonological word. This point will not be discussed here, as we are taking the result of this study as evidence that naming latencies are affected by the phonological processing of *no more* than the first phonological word.

phonological encoding make different predictions about the effects of word frequency on NP production. An effect of the frequency of the noun is predicted only if the level at which frequency effects occur has a scope of processing that includes the noun of the NP. Thus, the investigation of the effects of word frequency on NP production provides a test for the different assumptions simultaneously at work in a model of speech production. Here we report two picture naming experiments where participants named the pictures with adjectival (determiner + adjective + noun) NPs. In the experiments we manipulated orthogonally the frequencies of the two items (adjective and noun) that compose the NP.

EXPERIMENT 1: ADJECTIVE AND NOUN FREQUENCY EFFECTS IN NP PRODUCTION

In Experiment 1, we tested whether word frequency affects the production of multi-word utterances. Participants were asked to produce NPs (determiner + adjective + noun) using adjectives and nouns that varied in frequency. As argued above, since the scope of grammatical encoding is thought to encompass the whole NP, if the frequency effect is located at that level of representation, we should expect to observe faster naming latencies for NPs with high frequency nouns than with low frequency nouns. For the same reason, we also expect to find frequency effects for the adjective. By contrast, if the frequency effect is located at the level of phonological encoding, the probability of observing frequency effects will depend on the extent to which the phonological planning unit encompasses one or more phonological words. If the unit of phonological encoding is only one phonological word, then a frequency effect is only expected for the adjective; if the unit of phonological encoding encompasses at least two phonological words, then frequency effects should be observed for both adjective and noun.

Method

Participants. Eighteen participants took part in the experiment. They were all native speakers of English and reported normal or corrected-to-normal vision. None reported problems recognising colours in everyday life or during the experiment.

Materials. We selected 32 pictures of common objects, 16 with high frequency (HF) names (average: 174 occurrences per million in Francis & Kucera, 1982; range: 58–662) and 16 with low frequency (LF) names (average: 13 occurrences per million; range: 1–36). The list of materials is provided in the Appendix. Most of the pictures (all but four) were selected from psychology picture collections (Cycowicz, Friedman, Rothstein, &

Snodgrass, 1997; Snodgrass & Vanderwart, 1980). Age of acquisition ratings for the materials in this and the following experiment were obtained by asking 23 participants to rate, on a scale from 1 to 7, the age at which they thought they might have learnt the words they were presented. The procedure followed that used in earlier studies (Carroll & White, 1973a). The ratings show that the two groups of picture names were as different in AoA as they were in frequency (HF group = 1.90, LF group = 2.97; $p < .01$). The names of the two sets of pictures were matched for number of syllables (HF group = 1.2, LF group = 1.3).

Each picture was presented in eight different colours, four of high frequency (blue, black, green, red; average frequency: 136 occurrences per million; range: 85–169) and four of low frequency (orange, pink, purple, and yellow: average frequency: 30 occurrences per million; range: 8–52). Because there are not many colour names, we could not avoid a confound of frequency and length. However, this feature of the design is irrelevant for evaluating the frequency effect of the nouns. This is because, all the pictures appeared in all the possible colours, and therefore a difference in the adjective's length will equally affect low frequency and high frequency nouns (see more about this issue in the discussion of Experiment 2).

Care was taken not to select any picture that had a "natural" specific colour (e.g., banana). In other words, the pictures were always plausible objects when presented in the different colours. To create the coloured version of the pictures, the surfaces of black outline pictures were coloured. In the case of pictures coloured in black, the contour was converted to light grey in order to keep it visible. The pictures had similar sizes and they were presented on a white rectangle (245 pixels wide × 240 pixels high).

We also selected eight pictures with similar characteristics to the experimental items for use in the training and warm-up trials.

Procedure. The experiment was run on a Macintosh G3 PowerPC computer and was controlled by the software package Psyscope 1.2.2 (Cohen, MacWhinney, & Flatt, 1993). Participants were tested individually.

The experiment had two parts. In the first part, participants were familiarised with the experimental materials and with the task. They were first asked to name the pictures (presented in black and white) with bare names (e.g., kite). Their response triggered the appearance of the intended name of the picture on the screen. Participants were instructed to use the word provided by the computer in the experimental trials. Then, participants were asked to name coloured versions of the eight training pictures by naming them with adjectival NPs. In these trails the procedure mirrored the experimental procedure described below.

In the second part of the experiment, the same pictures were presented in eight different colours and participants were asked to name the pictures using adjectival noun phrases (e.g., "the blue kite"). In the experimental part, each picture was presented eight times in four blocks. The presentation of the pictures in each block was randomised with the following restrictions: (a) before any repetition of a given picture all the other pictures had to have been presented already; (b) the picture's names in two successive trials were neither semantically nor phonologically related; (c) the same colour was not presented in two successive trials. Furthermore, in a given block, the colour of the pictures was distributed similarly across HF and LF words. At the beginning of each experimental block, two filler pictures were presented as warm-up trials.

Participants were instructed to name the pictures as fast and as accurately as possible. Each trials consisted of the following events: first a fixation point (+) for 500 ms, then a black screen for 300 ms and then the picture to be named. The picture remained on the screen until the voice key detected the response or when a deadline of 2500 ms was reached without an overt response. The next trial started 1500 ms after the participant's response. The experimenter monitored the participants' responses. The experiment lasted about 30 minutes.

Analyses. We excluded from the analysis trials in which the voice key malfunctioned (1.2%). Trials in which participants stuttered or gave an incorrect response (3.9%) along with outliers (1.2%) (more than three standard deviations from the participants' mean) were treated as errors. The overall error rate was therefore 5.1%. In the analyses of response latencies and error rates, we examined the effect of the factors "Noun Frequency" (high or low) and "Adjective Frequency" (high or low). These two variables were treated as within variables with one exception—in F_2 analyses "Noun Frequency" was considered as a between-item variable.

Results and discussion

An overview of the data is provided in Table 1. Both noun and adjective frequencies significantly affected naming latencies. Responses were faster to NPs containing high frequency than low frequency nouns [NPs with HF nouns: 686 ms; NPs with LF nouns: 703 ms; $F_1(1, 17) = 9.06$, $MSE = 526.3$, $p < .01$; $F_2(1, 30) = 5.83$, $MSE = 727.7$, $p = .02$]. Similarly, responses were faster to NPs with high frequency than low frequency adjectives [NPs with HF adjectives: 672 ms; NPs with LF adjectives: 717 ms; $F_1(1, 17) = 33.0$, $MSE = 1065$, $p < .01$; $F_2(1, 30) = 200$, $MSE = 302.0$, $p < .01$]. The interaction between the two variables was not significant [$F_1(1, 17) = 3.04$, $MSE = 89.40$, $p = .10$; $F_2(1, 30) = 1.96$, MSE, 154.0, $p = .17$].

TABLE 1
Mean naming latencies (M, in ms), standard deviations (SD) and error rates (% Err) per condition in Experiment 1 for the production of adjectival NPs

Adjective Frequency	*Noun frequency*						*Noun: Low – High*
	High			*Low*			
	M	*SD*	*% Err*	*M*	*SD*	*% Err*	
High	662	100	5%	682	92	4%	20
Low	711	109	5%	723	108	7%	12
Adj: Low – High	49			41			

In the analysis of the error rates we found no effect of the frequency of the noun [$F_1(1, 17) = 1.0$; $F_2(1, 30) = 1.1$]. There was an effect of the frequency of the adjective [$F_1(1, 17) = 7.73$, $MSE = .001$, $p = .01$; $F_2(1, 30) = 10.1$, $MSE = .0004$, $p < .01$]: participants produced more errors with NPs containing low rather than high frequency adjectives. A significant interaction between the two factors [$F_1(1, 17) = 5.58$, $MSE = .001$, $p = .03$; $F_2(1, 30) = 8.09$, $MSE = .0004$, $p < .01$] indicates that the effect was restricted to the condition where both the noun and the adjective were of low frequency (see Table 1).

The results of this experiment showed clear noun and adjective frequency effects in the production of adjectival NPs. This result extends the classic frequency effect (Oldfield & Wingfield, 1965) to those cases in which participants produce multi-word utterances. As argued in the Introduction, the more relevant result of this experiment for models of lexical access is the observation of frequency effects for the noun of the NP. Before discussing the implications of this effect it is important to test its reliability with a larger set of pictures.

EXPERIMENT 2: A REPLICATION

In order to assess the reliability of the frequency effect in the production of adjectival NPs, in Experiment 2 we included a larger set of materials (50 pictures) presented in four different colours. Participants were instructed to produce a full adjectival NPs.

Method

Participants. Fifteen participants from the same population as in Experiment 1 took part in this experiment. None had participated in Experiment 1.

Materials. We selected 50 pictures of common objects, 25 with high frequency names (average: 148 occurrences per million; range: 46–662) and

25 with low frequency names (average: 9 occurrences per million; range: 1–20). The list of materials is provided in the Appendix. As before, the two groups of pictures differed in AoA (HF group = 2.1; LF group = 2.9; $p < .01$). The two sets of pictures and their names were matched for number of syllables (HF group = 1.2, LF group = 1.3; $F < 1$). The same criteria for the selection of the materials as in the previous experiment were followed here. Most of the pictures (37) used in this experiment had not been used in Experiment 1. The pictures were presented in four different colours that varied in frequency (high frequency: green and red; low frequency: purple and yellow), and also in length.

The procedure, the details of the design, and the analyses that were conducted for this experiment were identical to those of Experiment 1.

Results and discussion

Following the same criteria as in Experiment 1, 8.5% of the data points were scored as errors (participants stuttered or gave an incorrect response – 7.3%, outliers – 1.2%) Voice key malfunctioning accounted for 0.3% of the data.

An overview of the data is provided in Table 2. Both noun and adjective frequency affected naming latencies [NPs with HF nouns: 649 ms; NPs with LF nouns: 676 ms; $F_1(1, 14) = 16.7$, $MSE = 661.2$, $p < .01$; $F_2(1, 48) = 12.9$, $MSE = 1570$, $p < .01$; NPs with HF adjectives: 654 ms; NPs with LF adjectives: 669 ms; $F_1(1, 14) = 4.55$, $MSE = 735.9$, $p = .051$; $F_2(1, 48) = 3.55$, $MSE = 400.0$, $p = .066$]. The interaction between the two variables was not significant [both Fs < 1]. In the analysis of the error rates none of the comparisons was significant.

The results of this experiment are similar to those of Experiment 1. NP naming latencies were faster when the noun in the NP is high in frequency than when it is low in frequency. Along the same lines NPs with high frequency adjectives were named faster than NPs with low frequency adjectives.

TABLE 2
Mean naming latencies (M, in ms), standard deviations (SD) and error rates (% Err) per condition in Experiment 2 for the production of adjectival NPs

	Noun frequency						
	High			*Low*			
Adjective Frequency	*M*	*SD*	*% Err*	*M*	*SD*	*% Err*	*Noun: Low – High*
High	642	114	7%	667	131	9%	25
Low	655	112	8%	684	138	9%	29
Adj: Low – High	13			17			

Finally, as in Experiment 1 we found no interaction between the effect of frequency of the adjective and the effect of frequency of the noun. In other words, the frequency effects of the adjective and the noun were additive, and the frequency effect for the noun appeared regardless of whether the adjective was low or high in frequency.

However, as described in the Method sections of Experiments 1 and 2, the frequencies and the lengths of the adjectives are correlated, and this complicates the interpretation of the frequency effect of the adjective. All low frequency adjectives (except "pink") were disyllabic and all high frequency ones were monosyllabic. Thus, the frequency effect for the adjective could either be due to the difference in frequencies or in length. Nevertheless, there are at least two reasons to believe that part of the effect reported here is due to a difference in frequency. First, the syllable length effect in picture naming is not a robust effect. The only two studies that have addressed whether the number of syllables affects the onset of articulation in picture naming have produced contrasting results. While Klapp, Anderson, and Berrian (1973) found a difference of 14 ms between monosyllabic and disyllabic words, Bachoud-Lévi, Dupoux, Cohen, and Mehler (1998) failed to observe any length effect in English and French – even when comparing monosyllabic, disyllabic, and trisyllabic words. Second, we failed to find a length effect in a re-analysis of the data from Experiments 1 and 2. Since the frequency and length of the adjectives are highly correlated, in this post-hoc analysis we explored whether the length of the nouns affected naming latencies. For both high and low frequency nouns, naming latencies for the NPs with monosyllabic and disyllabic nouns were compared. The same adjectives were included in the two sets of NPs. The results of these analyses did not reveal any length effect. Monosyllabic and disyllabic low frequency nouns produced similar naming latencies (Experiment 1: 701 ms vs. 705 ms, respectively; both Fs < 1. Experiment 2: 678 ms vs. 671 ms; Fs < 1). The same pattern was observed for high frequency nouns (Experiment 1: 681 ms vs. 690 ms; both Fs < 1). The analysis was not conducted with the high frequency nouns from Experiment 2 because among the 25 nouns there were very few nouns (3) that were not monosyllabic.

Thus, it appears that the effect observed for the adjectives in our experiments was most likely due to the frequency of the adjectives. Nevertheless, the interpretation of the adjective frequency effect and its relationship to the noun frequency effect should be cautious.

GENERAL DISCUSSION

In this study we investigated some aspects of the organisation of lexical retrieval and the scopes of grammatical and phonological encoding during the production of multi-word utterances. We took as a starting point some assumptions that have been made about the processes involved in the preparation of multi-word utterances (e.g., Costa & Caramazza, in press; Meyer, 1996; Schriefers et al., 1999; Schriefers & Teruel, 1999). These assumptions together with assumptions about the classic frequency effect that is observed in single-word experiments (e.g., Caramazza, Costa, Miozzo, & Bi, in press; Dell, 1990; Jescheniak & Levelt, 1994; Levelt et al., 1999) were used to derive specific predictions regarding the production of NPs. Crucially, whether or not a frequency effect should be expected during the production of NPs depends on the locus of the frequency effect and on the scope of encoding that precedes articulatory processes.

The results of the two experiments reported here are clear: adjectival NPs with high frequency nouns were produced faster than adjectival NPs with low frequency nouns. In other words, frequency effects for the noun of the NP are not only observed when the noun is the first word of the utterance but also when it is located in the third position of the NP (see Figure 1). As we argued in the Introduction this effect sets constraints on the assumptions that a model of lexical access can hold simultaneously.

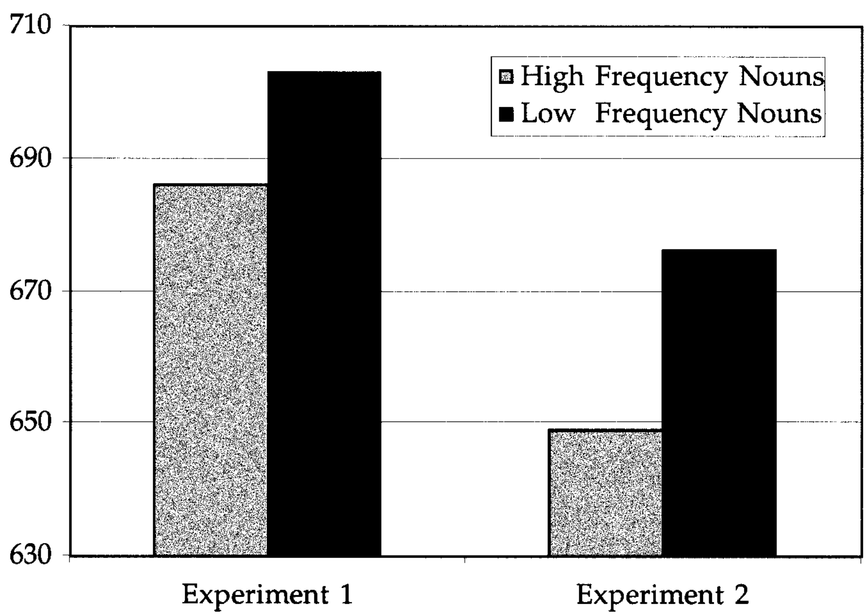

Figure 1. Naming latencies (in ms) for the production of adjectival NPs in Experiments 1 and 2 as a function of the frequency of the noun: high frequency nouns – e.g., "the blue car" – or low frequency nouns – e.g., "the blue kite". The data are collapsed over adjective frequency.

The results obtained in Experiments 1 and 2 are compatible with the assumption that frequency effects are located at the level of grammatical encoding, where lexical nodes are retrieved. Since, by hypothesis, grammatical encoding includes all the lexical items in the NP, the frequency of the noun should affect naming latencies, as observed in our experiments. However, the frequency effect for the noun in adjectival NPs is problematic for those models that hold both of the following assumptions: (a) the frequency effect has its origin in the retrieval of the phonological properties of the noun (Jescheniak & Levelt, 1994; Levelt et al., 1999), and (b) phonological planning units do not comprise more than one phonological word (as suggested by Levelt, 1989; Levelt et al., 1999; Meyer, 1996; Schriefers & Teruel, 1999; Wheeldon & Lahiri, 1997). According to a model of this type, the level of activation of the phonological units that fall outside of the first phonological word should not affect naming latencies. This is because the minimal unit needed to access the next level of processing (the phonetic level) is the first phonological word, and the noun of the adjectival NPs used in our experiments falls outside this planning unit. Our results are clearly at odds with this prediction, but it is unclear which of the two assumptions of this model is wrong. In other words, it is possible that either the assumption about the locus of the frequency effect is wrong, or that the assumption about the scope of phonological encoding is wrong, or that both are wrong. Nonetheless, it is possible to entertain different modifications of such a model that can accommodate our results. One possible change is to locate the frequency effect at the level of grammatical encoding.[3] As we have seen, models that make this assumption are compatible with the results reported here. Another possibility is to drop the assumption that the unit of phonological encoding comprises only the first phonological word. And, finally, we could assume that frequency has its effects at the level of lexical selection for grammatical encoding and that the scope of phonological encoding is larger than one phonological word. This last possibility is the one that seems to be most consistent with recent experimental results. First, the independent evidence motivating the location of the frequency effect at the phonological level has been recently challenged by Caramazza et al. (in press). Second, results from studies using different experimental paradigms (picture-word interference and determiner selection experiments: Alario & Caramazza, in press; Costa & Caramazza, in press; Miozzo & Caramazza, 1999) seem to suggest that the scope of phonological encoding may encompass elements that fall outside the first

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[3] In principle the frequency effect does not need to be located exclusively at a certain level of processing in the system. It could well be that frequency affects several of the processes involved in lexical retrieval.

phonological word (see Costa & Caramazza, in press, and Wheeldon, 2000, for a discussion of the contrasting results concerning the role of the phonological word in speech production).

Finally, there is another result reported in our experiments that deserves some attention: the additivity of the adjective and noun frequency effects. Although our experiments were not explicitly designed to study this issue, this result could provide us with some initial insight into the time course of lexical retrieval in NP production.

Two contrasting views could be offered regarding the time-course of lexical retrieval and the coordination of the processes of selection of the noun and the adjective in an NP (for a discussion of these issues see Schriefers, 1992; Schriefers et al., 1999). One view assumes that the different items of the NP are retrieved in parallel (e.g., Kempen & Huijbers, 1983; Schriefers et al., 1999). The other view assumes that the retrieval of the two lexical nodes proceeds in a strictly sequential manner, in which the retrieval of the second element only starts after the retrieval of the first has been completed. Which of these two processing assumptions best accounts for the observed frequency effects in NP production?

Consider first the assumption of parallel processing. A lexical retrieval process organised along these lines allows the following predictions (see Figure 2a). If the retrieval of one of the two items is slower than the retrieval of the other item (the noun in Figure 2a), then the lexical retrieval time will be solely determined by the lexical node that takes the most time to be retrieved. This is because any variation in the retrieval time of, for

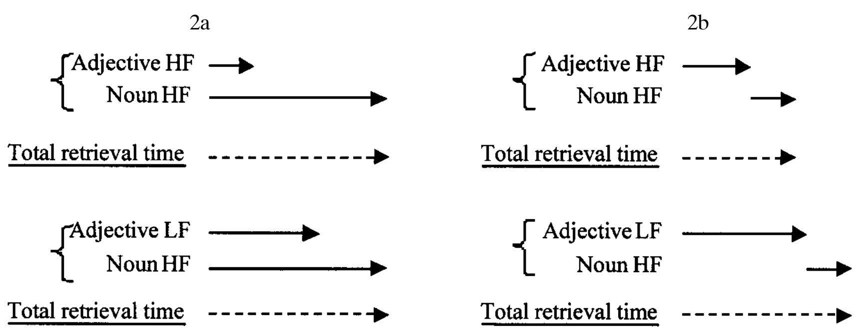

Figure 2. Schematic representation of the retrieval times for the high and low frequency adjectives and nouns at the level where frequency effects occur (arrows indicate retrieval time). Figure 2a represents independent parallel retrieval of the noun and the adjective. In the example, retrieval time is only determined by the noun, as any variation in the retrieval time of the adjective would be masked by the longer retrieval of the noun. Figure 2b represents sequential retrieval (with adjective first as an example). Any variation in the retrieval time of the adjective will add up to the retrieval time of the noun. Therefore, both frequency effects will be additive.

example, the adjective would be masked by the longer retrieval time needed for the noun. Thus, this hypothesis does not predict the observed additive effects of the frequencies of the noun and the adjective. Of course, this interpretation assumes not only that the retrieval of the two lexical nodes occurs in parallel but also that they occur independent of each other. However, it is possible that when two lexical nodes are being processed simultaneously, the speed with which one lexical node is retrieved depends on the ease with which the other is retrieved (e.g., Schriefers et al., 1999). Taking the latter view, and depending on how one implements this dependency, it may be possible to model the additive effects observed in our experiments.

The additivity of the effects of noun and adjective frequency observed in our study finds a natural explanation in the sequential processing account (see Figure 2b). According to this view, any delay in the retrieval of the first item will delay the point in time at which the process of retrieval of the second item starts. If the system requires that all items within a defined scope of processing be retrieved before processing at the next stage can start, both frequency manipulations would be expected to have an impact on naming latencies, and their effects would be additive. Note that the sequentiality assumption need not be as strict as having to assume that the retrieval of the second item happens if and only if the first item has been fully retrieved. A weaker version of the hypothesis would state that lexical retrieval is "staggered" in such a fashion that the retrieval of the second element starts as soon as processing of the first item has proceeded up to a specified level (but not complete retrieval). If the time to reach such a level were a function of the word's frequency, then the onset of retrieval of the second element would depend on the frequency of the first element, leading to the observed additive effects of frequency.

Whatever the merits of these speculations about the organisation of the lexical access of multiple words, we can reject those models that assume that the lexical nodes of an NP are retrieved in parallel *and* that the ease with which any one element is retrieved is independent of the retrieval of the others (e.g., Kempen & Huijbers, 1983).[4]

To conclude, in two picture naming experiments where participants named pictures with adjectival NPs (e.g., "the blue kite"), we found additive effects of the frequency of the adjective and of the frequency of

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[4] Some results have been interpreted as supporting the parallel retrieval of multiple lexical nodes. For example, Kempen and Huijbers (1983) observed that Dutch speakers named the action (V; "kick") depicted in a picture as fast as they named the actor *and* the action (SV "the girl kicks"; but see Schriefers, Teruel and Meinshausen, 1998). According to the authors, this result suggests that lexical access should run in parallel. However, and regardless of the reliability and generalisability of the phenomenon (Schriefers et al., 1998, found faster SV than V latencies in German), Kempen and Huijber's results are not incompatible with a

the noun. The finding that noun frequency had an effect on naming latencies is compatible with models where frequency is located at the level of grammatical encoding. However the results are problematic for models which assume that frequency affects the level of phonological encoding *and* that the scope of phonological encoding is limited to the first phonological word. Furthermore, the additivity of the effects of noun and adjective frequency suggests that the lexical items in an NP are not retrieved in parallel. Some type of sequentiality or dependency between the retrieval processes of the two items seems to be required.

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sequential model. For example, one could argue that when naming an action by itself (V), speakers cannot avoid to process also the actor as well. Thus, regardless of whether or not the subject is overtly produced, participants may nevertheless have retrieved it. This is especially plausible in languages like Dutch, in which in natural contexts (a) the form of the verb depends on the subject, and (b) the subject of the utterance is always overtly produced. Thus, the V and SV formats may require the retrieval of the same lexical nodes.

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APPENDIX

Materials used in Experiment 1

High freq. nouns	*F-K freq.*	*Low freq. nouns*	*F-K freq.*
BOX	82	BRUSH	36
CAR	393	CANE	13
CHAIR	89	COMB	6
DOOR	348	CROWN	19
DRESS	63	DRUM	26
FLOWER	78	FUNNEL	2
HAT	71	KITE	1
HOUSE	662	LANTERN	15
KNIFE	86	RULER	13
SHOE	58	SADDLE	26
STAR	58	SCARF	4
TABLE	242	SKULL	5
TRUCK	80	SWORD	12
WALL	224	TRUMPET	6
WHEEL	77	VASE	15
WINDOW	172	VEST	4
High freq. adj.	*F-K freq.*	*Low freq. adj.*	*F-K freq.*
GREEN	85	PURPLE	11
BLUE	126	ORANGE	8
BLACK	165	PINK	47
RED	169	YELLOW	52

Freq., frequency; F-K, Francis & Kucera (1982); Adj., adjective.

Materials used in Experiment 2

High freq. nouns	*F-K freq.*	*Low freq. nouns*	*F-K freq.*
BALL	123	ARROW	20
BED	139	BASKET	19
BOMB	68	BOW	13
BOOK	292	BROOM	2
BOTTLE	90	CANOE	8
BOX	82	CANON	11
CAR	393	CASTLE	12
CHAIN	60	COMB	6
CHURCH	451	CRANE	2
COAT	52	DRESSER	3
CUP	58	FLAG	18
DESK	69	FLUTE	1
FENCE	46	GLOBE	14
GUN	142	GLOVE	16
HAT	71	HAMMOCK	5
HOUSE	662	HARP	1
KEY	71	HELMET	3
KNIFE	86	KITE	1
PLANE	138	ROPE	19
SHOE	58	SCARF	4
STAR	58	SHIELD	8
TABLE	242	SOCK	10
TELEPHONE	79	SPOON	6
TRAIN	86	STOOL	8
WHEEL	77	VASE	4
High freq. adj.	*F-K freq.*	*Low freq. adj.*	*F-K freq.*
GREEN	85	PURPLE	11
RED	169	YELLOW	52

Freq., frequency; F-K, Francis & Kucera (1982); Adj., adjective.