

Accessing object names when producing complex noun phrases: Implications for models of lexical access

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Abstract

Producing connected speech involves coordinating the retrieval of various types of information: a) lexical items, b) its grammatical properties, and c) its phonological composition. In this article we explore these processes during the production of compound noun phrases (NPs) such as “the dog and the car”. We report three experiments in which we investigated the scope and degree of incrementality of planning. In the first experiment, naming latencies were longer for compound NPs with semantically related items (e.g., “the dog and the horse”) than for compound NPs with unrelated items. In the second experiment, the lexical frequency of the two nouns in the NP was manipulated. The results showed an effect of the frequency of the first item, but no effect of the frequency of the second. Finally, in the third experiment, naming latencies were not affected by the phonological similarity between the two nouns of the NP. These results provide evidence for the fact that the availability of the second lexical item in this type of utterance does not affect the onset of articulation. These findings, as well as other data previously reported in the literature, are discussed in relation to the issue of the coordination of the retrieval of various lexical items.

Keywords: Noun phrases production, syntactic planning, phonological planning.

La recuperación de los nombres en la producción de sintagmas nominales complejos: implicaciones para los modelos de acceso léxico

Resumen

La producción del habla en oraciones requiere coordinar la recuperación de varios tipos de información: de unidades léxicas, de propiedades gramaticales y de composición fonológica. En este artículo exploramos estos tres tipos de procesos durante la producción de sintagmas nominales (SN) compuestos del tipo “el perro y el coche”. Reportamos tres experimentos en los que investigamos el alcance de la planificación incremental en este tipo de producciones. En el primer experimento, se observaron mayores latencias de denominación cuando los ítems del SN compuesto estaban semánticamente relacionados (p.ej., “el perro y el caballo”) que cuando no lo estaban. En el segundo experimento, se manipuló la frecuencia léxica de los dos ítems del SN compuesto. Los resultados arrojaron un efecto de frecuencia del primer ítem, pero ningún efecto de frecuencia del segundo ítem. Finalmente, en un tercer experimento, las latencias de denominación no se vieron afectadas por la similitud fonológica entre los dos nombres del SN compuesto. Estos resultados sugieren que la disponibilidad del segundo elemento léxico en este tipo de construcciones no afecta al inicio de la articulación. Esta nueva evidencia, juntamente con otra reportada previamente en la literatura, se discute en referencia a la coordinación de la recuperación de varios ítems léxicos.

Palabras claves: Producción de sintagmas nominales, planificación sintáctica, planificación fonológica.

Acknowledgments: The work reported here was supported in part by NIH grant DC 04542, and by the “Ramón y Cajal” program from the Spanish government. We thank Alfonso Caramazza, Zenzi Griffin, Saamah Abdullah, and Scott Sinnett for their helpful comments.

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Introduction

The production of phrases requires the coordination of the various processes involved in the selection of a) the concepts to be expressed, b) the lexical items corresponding to these concepts and c) the grammatical and phonological properties of the lexical items. For example, when producing noun phrases (NPs) of the type "the dog and the car", the speaker needs to retrieve the semantic information corresponding to the two objects ("dog" and "car"), and has to build up a conceptual message that conveys the relationship between both elements (e.g., copulative). Once this so-called preverbal message has been conceptualized, the speaker needs to retrieve the lexical nodes that correspond to the different elements of the message and order them according to the grammatical rules of the language being spoken. The processes involved in that stage have been labeled under the term grammatical encoding. After the retrieval of the lexical items, the grammatical encoder assigns the different grammatical roles to them, and the retrieval of the morpho/phonological properties of the selected lexical items starts. This latter processing is the so-called phonological encoding, and it is responsible for the selection of the phonological properties of the words according to the phonological context in which they appear. The final stage prior to articulation is the retrieval of the articulatory gestures corresponding to the phonological shape of the utterance.

One of the central issues in speech production concerns the units of representation and the processing dynamics at each of these levels. In order to address this issue one can explore how much information the speaker plans in advance at each level of representation before articulation is triggered. In other words, how much the speaker looks ahead when she is computing one part of her intended utterance. The experiments reported in this study aimed at exploring some issues related to the size of the planning units during the production of compound NPs.

It is generally hypothesized that the production system can process in parallel different parts of the utterance at different levels of representation (e.g., Kempen & Hoenkamp, 1987; Levelt, 1989). This property of the speech production system has been labeled under the term incrementality. Although the specific ways in which incremental processing is implemented into the system are controversial, there are also a few shared assumptions about how linguistic encoding is organized. The first common assumption is that the scope of planning is different for different levels of representation (e.g., grammatical and phonological levels). The second is that this scope is larger for grammatical than for phonological encoding. The evidence supporting these two assumptions comes both from the study of the spontaneous slips of the tongue and from experimental results. We discuss these two sets of evidence in turn, paying special attention to the experimental results.

One of the most robust effects observed in speech errors is the fact that lexical exchanges tend to involve words that are relatively far apart in the intended utterance. For example, in the lexical error "give the baby to the banana" (from Meyer, 1996), the words "baby" and "banana" have been transposed. These lexical errors are supposed to reflect an error at the level at which lexical nodes are inserted into the syntactic frame. The fact that the exchanging elements belong to different phrases has been interpreted as suggesting that the elements of the whole clause are retrieved before articulation is triggered. Following the same line of reasoning, the fact that the elements that interact in phonological exchange errors such "beft lemisphere" (from Fromkin, 1971) belong to words that are adjacent in the utterance has been interpreted as suggesting that the scope

of processing at the phonological level is relatively small (e.g., one phonological word or phrase)¹.

Despite the fact that the analysis of spontaneous slips of the tongue has been very useful to characterize the organization of the speech production system, it also shows important limitations. For one thing, one may claim that these errors occur when the speech production system derails momentarily from its normal functioning and, as a consequence, encodes simultaneously more (or less) elements than it is supposed to encode at a given level of representation. It is therefore important to explore the issue of incrementality in error-free speech production, and this has been done experimentally by means of two main strategies.

First, researchers have explored whether the syntactic complexity of an utterance affects the speed of onset triggering. Consider the study conducted by Smith and Wheeldon (1999), in which participants were asked to describe a scene with different utterance formats. In one case, participants were required to produce utterances such as “the car and the apple move up”, in which the sentence starts with a compound NP, while in the other condition they were asked to produce utterances of the type “the car moves up and the apple moves up”, in which the sentence starts with a simple NP. Speech onset times were faster for the latter type of utterance than for the former, and this was interpreted as suggesting that the two nouns of the compound NP have to be retrieved from the lexicon before speech onset can be triggered (see also Levelt and Maasen, 1981)².

The second strategy followed to study the issue of incrementality in language production has been to explore whether naming latencies are affected by the availability of elements that are placed at different locations in the utterance. The basic reasoning behind all these studies is the following: if speech onset times are affected by the availability of a given element in the utterance, then one could conclude that such an element has been processed, to some extent, before articulation is triggered (see General Discussion for a discussion of this reasoning).

The first study that explored this issue was conducted by Meyer (1996; see also Schriefers, 1993). Meyer asked participants to name two pictures by means of compound NPs (e.g., “the arrow and the banana”), while ignoring the presentation of an auditory distractor word that could be either semantically or phonologically related to the first or second noun of the NP. When the distractor was related to the first noun of the NP (e.g., “bow” or “art” for arrow), semantic interference and phonological facilitation were observed - semantically related distractors (e.g., “bow”) slowed down naming latencies, and phonologically related distractors (e.g., “art”) sped up naming latencies; both compared to an unrelated distractor word (e.g., “car”). More interesting is the pattern of results observed when the distractor word was related *to the second noun of the NP*. In this case, semantically related distractors (e.g., “apple”) also slowed down naming latencies. However, naming latencies for phonologically related distractors (e.g., “ban”) were similar to those for unrelated distractors. Following the assumption that the semantic interference effect reflects a difficulty in lexical selection, Meyer concluded that speakers have accessed the lexical nodes corresponding to both nouns of the compound NP before the onset of articulation. Also, and given the assumption that the phonological facilitation effect reflects how easily the phonological segments of a word are retrieved, the lack of such an effect for the second noun of the NP led Meyer to conclude that the phonological properties of the second noun of the NP were retrieved during the articulation of the first part of the NP. These results can be taken as evidence

supporting the notion that naming latencies depend, *inter alia*, on how fast lexical items that are not placed in the first positions of the utterance are retrieved during grammatical encoding. This interpretation would also be in accordance with the idea that at the grammatical level, the elements of the whole phrase are retrieved before articulation commences. Furthermore, the fact that the availability of the phonological properties of the second element of the NP did not affect naming latencies suggests that at the level at which these properties are retrieved the scope of planning is rather small, no more than one phonological word³. However, other researchers have reported some data that are in conflict with these two conclusions.

Let us start with the idea that the scope of the grammatical encoding encompasses at least the two nouns of a compound NP. The first evidence that is at odds with this notion was reported by Meyer (1997). In a picture-word interference study very similar to the one presented above (Meyer, 1996), participants were asked to name pictures by means of compound NPs while ignoring semantically related distractors. In this case, the two pictures varied in size and participants had to name them with compound NPs of the type “the big arrow and the small banana”. Unlike previous results, the semantic interference effect was *only* present when the distractor word was related to the first object but not to the second object of the scene. In a follow-up experiment, in which participants were asked to ignore the size of the objects and just produce a compound NP (e.g., the car and the arrow) as the ones produced in Meyer (1996), no semantic interference effect for the second object of the NP was observed either. These results are difficult to interpret, since it is not clear why the fact that the objects had different sizes removed the semantic interference effect for the second noun of the NP, even when participants were instructed to ignore such a dimension. At any rate, these results cast some doubts about the reliability of the semantic interference effect observed for the second noun of the NP in previous studies (Meyer, 1996).

The second study that has failed to find evidence supporting the idea that the availability of the second noun of a compound NP affects naming latencies was conducted by Griffin (2001). In this study participants were asked to describe three pictures by using the sentence frame “The A and the B are above the C”. The critical manipulation for our purposes here refers to two properties of the second picture of the compound NP (object B). Griffin manipulated how easily the name of the second object could be selected by varying its name agreement (or codability) and also its word-frequency. For example, object B could be a picture with a high name agreement (e.g., apple) or with a low name agreement (e.g., television, TV, TV set, etc.). Given that objects with low name agreement are produced more slowly than objects with high name agreement, Griffin argued that if the speech latencies were to be dependent, to some extent, on how easily the second noun of the NP is retrieved, then the production of a compound NP would be faster when the second object had a high name agreement (and/or a high word-frequency) than when it had a low name agreement (and/or a low word-frequency). The results did not support such a prediction. Naming latencies were independent of the codability and word-frequency of the second noun of the NP. This result led Griffin to conclude that in the production of constrained compound NPs, participants can proceed with articulation without having retrieved the second noun of the NP, an element that it is presumably retrieved during the articulation of the first element⁴.

Thus, the results of Meyer (1997) and Griffin (2001) call into question the notion that, for articulation to proceed, the grammatical encoding of the two nouns of a compound NP needs to be completed. Therefore, these results would

suggest that under some circumstances the amount of planning carried out at the grammatical level may be much smaller than what it was thought to be.

Let us turn now to the issue of whether the scope of planning at the phonological level entails only the retrieval of one phonological word as suggested by the results of Meyer (1996; see also Wheeldon and Lahiri, 1997). In two recent studies the level of activation of elements placed outside the first phonological word has been shown to affect naming latencies (Costa and Caramazza, 2002; and Alario, Costa and Caramazza, 2002a). In these two studies participants were asked to name pictures by means of simple NPs of the type “the red car”. In Costa and Caramazza’s (2002) picture-word interference studies, Spanish and English speakers were asked to name pictures in their native language while ignoring distractor words. Naming latencies were slower when the distractor word was semantically related to the third word of the NP (the noun in the case of the English NP “the red car” and the adjective in the case of the Spanish NP “el coche rojo” [literally the car red]), suggesting that the availability of the lexical nodes of the whole phrase affects naming latencies (see also Martin and Freedman, 2001). However, and in contrast to Meyer’s results, phonologically related distractors to the third element of the NP also affected naming latencies. The phonological facilitation effects observed here are relevant because the element that is being primed (the noun in English and the adjective in Spanish) is located in the second phonological word. Thus, the authors interpreted this result as suggesting that the level of activation of the phonological properties of the second phonological word do affect naming latencies, a conclusion that in some respects contradicts that drew by Meyer (1996).

In Alario et al’s study, the frequency of the elements of simple NPs such as “the red car” was manipulated orthogonally. Interestingly, both the frequency of the noun (car) and the frequency of the adjective (red) affected naming latencies in an additive fashion. Crucially, in the NPs used in this study (“The red car”) the noun was placed in the second phonological word. Alario et al. (2002a) argued that, under the assumption that frequency effects reveal how fast the phonological form of the lexical items are retrieved, these results reveal that the availability of the phonological properties of the elements of the second phonological word affect naming latencies⁵.

The picture that emerges from these studies does not allow us to make a clear empirical generalization about the size of the planning units at the level of grammatical and phonological encoding. This is because there are contrasting results regarding the extent to which the availability of the second element of a compound NP affects naming latencies. On the one hand, Meyer’s (1996) results reveal that speech onset is delayed by an increase of lexical competition during the selection of the second noun of the NP (the semantic interference effect for the second noun), suggesting that the eventual speech triggering is somewhat dependent on the availability of that noun. A similar conclusion can be reached by the results of Smith and Wheeldon (1999). On the other hand, the fact that neither the name agreement nor the word-frequency of the second noun of the NP affected speech onset times, suggests that speech triggering is independent of the availability of such an element (Griffin, 2001; see also Meyer, 1997). Similarly, contrasting results have been reported with respect to the phonological encoding of items that are placed beyond the first phonological word of the utterance (see, e.g., Alario et al., 2002a; Costa & Caramazza, 2002; Meyer, 1996; see Levelt, 2002; and Alario, Costa, & Caramazza, 2002b for a discussion)

In this article, we present new experimental evidence regarding the issue of whether the availability of the second noun of a compound NP determines to some extent speech onset times. We asked participants to produce compound NPs (e.g., “the dog and the car”) while we manipulated some properties of the second noun of the NP. We followed a slightly different approach from that used in the studies presented above. In Experiment 1, the second noun of the NP was either semantically related (“the dog and the horse”) or unrelated (“the dog and the car”) to the first noun of the NP. If articulation proceeds without access to the second object of the NP then naming latencies should be independent of such a relationship between the two elements. However, if information about the second element of the NP is processed before articulation starts, then a semantic relationship between the two elements may slow down (or speed up) naming latencies. In Experiment 2, we explore whether naming latencies are affected by the frequency of the second noun of the compound NP. Finally, in Experiment 3, we address whether a phonological relationship between the two nouns of the NP affects naming latencies.

Experiment 1: Semantic effects in the production of compound NPs

In this experiment participants were asked to name picture pairs using compound NPs (e.g., “the dog and the car”). The critical variable that was manipulated was whether the two objects of a given pair were from the same semantic category or not (e.g., “the dog and the horse” vs. “the dog and the car”). Such a manipulation allows us to assess whether a semantic relationship between the two objects of the NP affects naming latencies, and therefore to explore whether the semantic information associated with the second element of the NP is processed before articulation commences.

If articulation triggering is independent of the properties and availability of the second element of the NP, then a semantic relationship between the two objects should be irrelevant for predicting naming latencies. However, if articulation triggering is somewhat dependent on the retrieval of the second element of the NP, then a semantic relationship between the two objects may affect speech onset times. This effect may arise because a delay (or facilitation), in the retrieval of either the first or the second noun of the NP. That is, it is possible that speakers start processing the second object of the NP before having selected the lexical node of the first element, therefore allowing any effect of a semantic relationship to affect the ease with which such an element is retrieved. On the other hand, it is possible that participants only start the linguistic processing of the second noun after having selected the lexical node corresponding to the first element of the NP. In this case any semantic relationship between the two objects should be irrelevant for the selection of the first noun of the utterance. In this scenario, it is still possible that the selection of the name of the second object is slowed down (or sped up) by the previous selection of a semantically related item. And, if articulation were to depend on the ease with which the second noun is retrieved then naming latencies should be affected⁶.

In short, if the articulation of a compound NP can start independently of the retrieval of the properties of the second noun of the NP, then a semantic relationship between the two nouns of the NP should be irrelevant for predicting naming latencies. In contrast, if the retrieval of some properties of the second object of the utterance can have an impact on speech triggering then it would be possible to find an effect by manipulating the semantic relationship between the two nouns of the utterance.

Method

Participants: Twenty-five participants took part in the experiment. They were all native speakers of English and reported normal or corrected to normal vision.

Materials: Forty-two pictures of common objects were selected to be used in the experiment. Most of the pictures were from the Snodgrass and Vanderwart (1980) collection. The target stimuli contained two pictures presented next to each other. To create the experimental conditions, every picture (e.g., “dog”) was paired with a picture of the same semantic category (e.g., “horse”) and with a picture from a different semantic category (e.g., “car”). This led to 42 experimental picture pairs (21 semantically related and 21 unrelated; see Appendix A). The names of the pictures that appeared in a given pair had similar lexical frequencies and were phonologically dissimilar. We also selected 8 pictures of the same type to be used as fillers and warm-up trials. Each experimental picture pair was presented twice. The position of the objects inside the pair was symmetrically changed. For example, participants had to name once the picture pair “dog/horse” (or “dog/car”) and once the pair “horse/dog” (or “car/dog”). On a given trial, the two individual pictures of an experimental stimulus appeared to the right and left of the fixation point. Participants always named the pictures from left to right. The two individual pictures had similar sizes; they were presented on black on a single white rectangle (500 pixels wide and 240 pixels high).

Procedure: The experiment was run on a Macintosh G3 PowerPC computer and was controlled by the software package Psycscope 1.2.2 (Cohen, MacWhinney & Flatt, 1993). Participants were tested individually. Before the experiment proper, they were familiarized with the experimental materials. During this familiarization phase each picture appeared alone on the screen, without any other paired picture. Participants were asked to name the individual pictures with bare names (e.g., “dog”). They were given feedback about the pictures’ names if their response differed from the expected response. After being familiarized with the materials, participants were familiarized with the experimental procedure. They received 8 picture pairs created from the filler pictures. The instructions and presentation procedure for these pictures were identical to those used in the experiment proper (see below).

During the experiment proper, the 42 picture pairs were presented twice in four different blocks. Each block contained 21 picture pairs. The presentation of the pictures in each block was randomized with the following restrictions: a) no individual pictures were repeated in the same block; b) approximately the same number of semantically related and unrelated pairs was presented in each block, c) picture pairs belonging to the same experimental condition (i.e., semantically related or unrelated) were not presented in more than 2 successive trials. At the beginning of each block, four filler picture pairs were presented as warm up stimuli. Several different block orders were constructed and similar numbers of participants were assigned to each order. Each trial had the following events: first a fixation point (a plus, “+”, sign) for 500 ms, then a blank screen for 300 ms and then the picture to be named. Participants were instructed to concentrate on the fixation point and to name the experimental picture as fast and as accurately as possible upon its appearance on the screen. They were asked to use compound NPs (e.g. “the dog and the car”) in which the pictures were named from left to right. The pictures remained on the screen until the voice key detected the response or when a deadline of 2500 ms was reached without overt response. The next trial started 1500 ms after the

participant's response. The experimenter monitored the participant's responses. The experiment lasted 30 minutes.

Analyses: Three types of responses were scored as errors: a) production of names that differed from those designated by the experimenter; b) verbal dysfluencies (stuttering, utterance repairs, production of nonverbal sounds that triggered the voice key); c) recording failures. Erroneous responses and outliers (i.e., responses exceeding 3 standard deviations from the participant's mean) were excluded from the analyses of response latencies. Separate analyses were carried out with subjects and items as random factors, yielding F_1 and F_2 statistics, respectively. One factor was analyzed: the semantic relationship between the two pictures of the pair (factor levels: semantically related vs. semantically unrelated). Table I shows the mean response latencies and error rates as a function of type of distractor and type of utterance.

Results and Discussion

Erroneous responses were observed on 9.5% of the trials. Error rates were slightly larger in the semantically related condition than in the unrelated condition ($F_1(1, 24) = 3.1, MSE = 3.37, p < .09; F_2(1, 41) = 2.0, MSE = 3.10, p < .17$). In the analysis of naming latencies, the main effect of semantic relationship was significant ($F_1(1, 24) = 6.5, MSE = 368.3, p < .017; F_2(1, 41) = 5.7, MSE = 861.3, p < .021$), revealing that semantically related picture pairs were named more slowly than semantically unrelated picture pairs.

TABLE I
Naming Latencies (ms.), standard deviations and error rates, by Type of pairing (semantically related, semantically unrelated) in Experiment 1
Latencias de denominación (en ms.), desviaciones estándar y porcentaje de errores por tipo de emparejamiento (semánticamente relacionado, semánticamente no relacionado) en el experimento 1

Type of pairing	Mean	SD	E%
Semantically Related (e.g., "the dog and horse")	729	111	10.5
Semantically Unrelated (e.g., "the dog and car")	714	100	8.3
Semantic Interference Effect (Related-Unrelated)	15		2.2

The results of this experiment indicate that the production of a compound NP is delayed when the two elements of the NP belong to the same semantic category than when they are from different semantic categories. This result suggests that before articulation is triggered the semantic properties of the second element of the NP have been accessed. This observation is consistent with Meyer's (1996) results, in which a delay in the retrieval of the second element of the compound NP slowed down speech onset times. Also, they suggest that at some level of representation the two elements of the NP have been processed to some extent before articulation starts (Smith & Wheeldon, 1999).

As discussed above, there are two ways in which this semantic interference effect may have arisen. The semantic interference may be revealing a slowing down in the processing of the lexical node of the first element of the NP. If participants have started encoding the second object before they have selected the lexical node corresponding to the first element of the NP, a semantic

relationship between the two elements may have interfered with the retrieval of the first element. That is, when trying to select the lexical node of the first element of the NP (e.g., “the dog” in “the dog and the horse”), the lexical node of a semantically related object (e.g., “horse”) may have been a more powerful competitor than the lexical node of a semantically unrelated object (e.g., “car”). This competition would delay the selection of the first element of the NP, and therefore would slow down naming latencies. Alternatively, the interference effect may have arisen as a carry over effect when retrieving the name of the second object of the NP. Under the assumption that speakers start the linguistic processing of the second object of the NP only after having selected the first noun, the semantic interference could have arisen during the selection of the second noun of the NP. This interference may come about because of the reactivation of the lexical node that has just been selected. For example, the selection of the word “horse” in the “the dog and the horse” may be delayed because its semantic representation reactivates to some extent the lexical node corresponding to the first object (e.g., “dog”), which in turn will compete for selection. Such a re-activation is not present when the second object is semantically unrelated (e.g., “car”). Whichever of these two explanations turns out to be correct (it is possible that both mechanisms contribute to the observed effect), what is important here is that both of them imply that the second object has been processed to the extent that it affects the onset of articulation.

The interpretation of the semantic interference effect presented above presupposes that a semantic similarity between the two objects of a given pair hampers the selection of lexical nodes. That is, a semantically related lexical node would compete for selection more than a semantically unrelated lexical node (see also Meyer, 1996, for similar arguments). However, strictly speaking, the results of Experiment 1 only reveals that, before articulation is triggered, speakers have had access to the semantic properties of the second element of the NP. That is, it is possible that the semantic interference effect reported here (as well as that obtained by means of the picture-word interference paradigm by Meyer, 1996) originates at the semantic level. This effect may be the result of a difficulty in determining which semantic representation needs to be lexicalized (a semantic competition), rather than a difficulty in selecting the proper lexical item (a lexical competition; see Costa, Mahon, Savova & Caramazza, 2003; Glaser & Glaser, 1989; Schriefers, Meyer and Levelt, 1990). For example, selecting the semantic representation of “horse” for lexicalization may be harder if the semantic representation of a semantic neighbor (e.g., “dog”) is activated concomitantly. We defer further discussion of this issue to the General Discussion.

At any rate, the presence of semantic interference effects can be taken as evidence that, at least, the semantic properties of the second element of the NP have been accessed before articulation starts, and that they may affect naming latencies.

In Experiment 2, we investigate the extent to which a lexical property of the second element of the NP affects naming latencies. Specifically, we test whether the word-frequency value of the second element of the NP predicts, *inter alia*, the onset of articulation.

Experiment 2: Frequency effects in the production of compound NPs

In this experiment we explore the role of word-frequency in the production of compound NPs. Word-frequency affects the speed and ease with which a

lexical node is retrieved (e.g., Oldfield & Wingfield, 1965; Jescheniack & Levelt, 1994). Therefore, if the frequency of the second noun of the utterance were to affect naming latencies, we could conclude that the ease with which that word is retrieved (and not only its semantic content) affects the triggering of articulation.

Word-frequency effects are present even for words that are not placed in the first position of the utterance. For example, Alario et al. (2002a) showed that determiner + adjective + noun NP naming (e.g., “the blue kite”), was faster when the head of the utterance (the noun) was of high-frequency than when it was of low-frequency (see also Meyer Sleiderink, & Levelt, 1998). Thus, it is possible to obtain word-frequency effects for words located at the end of simple NPs. However, there is also experimental evidence suggesting that the frequency value of the second element of a compound NP does not affect naming latencies (in sentences such as “the A and the B are above the C”; Griffin, 2001).

In this experiment the frequency values of the names of the two pictures included in a given pair were manipulated orthogonally. Thus, participants were asked to name four different types of pictures pairs: a) pairs in which both pictures had high-frequency names (HH condition; e.g., mouth/ball); b) pairs in which the first picture to be named had a high-frequency name and the second picture had a low-frequency name (HL condition; e.g., mouth/trunk); c) pairs in which the first picture to be named had a low-frequency name and the second picture had a high-frequency name (LH condition; e.g., trunk/mouth); and d) pairs in which both pictures had low-frequency names (LL condition; e.g., trunk/dagger). This design allows us to explore the contribution of the frequency values of the two nouns in the production of compound NPs.

We predict that NPs starting with a high-frequency word will be produced faster than NPs starting with a low-frequency word. Thus, the frequency value of the first noun of the NP will determine, among other things, speech onset times. More interesting are the predictions regarding the frequency value of the second element of the NP. If the onset of articulation depends to some extent on how easily the second noun of the NP is retrieved, then we should expect naming latencies to be faster when the second noun is a high-frequency word than when it is a low-frequency word. In contrast, if participants readiness to start articulation is independent of whether the second noun of the NP is easy to retrieve or not, then naming latencies should be independent of the word-frequency value of such an element.

Method

Participants: Twenty participants from the same population as in Experiment 1 took part in this experiment. None of them had participated in Experiment 1.

Materials: Fifty-six pictures of common objects were included in the experiment (see Appendix B). Half of them had low-frequency names (average = 6, range = 0-18) and the other half had high-frequency names (average = 91, range = 14-591). The difference between the two frequency values was significant ($p < .01$). In a pilot experiment in which 13 participants were asked to name the whole set of pictures, high-frequency words were named 29 ms faster than low-frequency words ($p < .01$). As in the previous experiment, participants were presented with two pictures side-by-side on each trial. The construction of the experimental picture pairs took into account the frequency of the picture names. Each picture (e.g., “mouth” of high-frequency) was paired

with a picture of the same frequency group (e.g., “ball” of high-frequency) and also with a picture of the other frequency group (e.g., “trunk” of low-frequency). The picture pairs were presented twice, with a variation in the order of the pictures of the pair (e.g., mouth/ball and ball/mouth). There were a total of 14 different pairs in each of the four different conditions. The pictures included in each pair did not have any obvious semantic or phonological relationship. All the other details of the method and procedure were identical to those in Experiment 1.

Analysis: The criteria for determining erroneous responses were the same that were used for Experiment 1. Separate analyses were carried out with subjects and items as random factors, yielding $F1$ and $F2$ statistics, respectively. Two factors (frequency of the first item and frequency of the second item) and their interaction were included in the analysis. Table II shows the mean response latencies and error rates in the different experimental conditions

TABLE II
Naming Latencies (ms.), standard deviations and error rates for the different word frequency conditions in Experiment 2
Latencias de denominación (en ms.), desviaciones estándar y porcentaje de errores de las diferentes condiciones de frecuencia léxica en el experimento 2

Type of pairing 1 st Noun - 2 nd Noun	Mean	SD	E%
High – High	705	90	12.5
High – Low	714	99	12.3
Low - High	736	107	14.5
Low – Low	721	91	15.2
Frequency Effects			
1 st Noun	18		2.4
2 nd Noun	3		0.3

Results and Discussion

Overall, 13.6% of the data points were scored as errors (see Table II). No effects were significant in the analysis of the error rates (all p 's > .2). In the analysis of naming latencies, the main effect of the frequency of the first element of the NP was significant ($F1(1, 19) = 12.6$, $MSE = 532.0$, $p < .002$; $F2(1, 27) = 4.5$, $MSE = 1836.0$, $p < .043$). The main effect of frequency of the second element of the NP was not significant (both F 's < 1). Finally, the interaction between the two factors reached a significant level only in the analysis by participants ($F(1, 19) = 6.791$, $MSE = 422.68$, $p < .017$; $F2(1, 27) = 1.13$, $MSE = 2795.7$, $p < .29$).

The results of this experiment reveal that naming latencies depend, among other things, on the frequency of the first element of a compound NP, replicating previous observations (Alario et al., 2002a; Griffin, 2001; Meyer et al., 1998). More importantly, the frequency of the second noun of the NP does not seem to affect participants' performance. This latter result is in accordance with the results obtained by Griffin (2001), in which the frequency value of the second noun of a complex NP in sentence naming (object B in “the A and the B are above the C”) did not affect naming latencies.

The fact that the onset of articulation in a compound NP is independent of whether the lexical node corresponding to the second element is a high-

or a low-frequency word, suggests that the ease with which that item is retrieved from the lexicon does not affect the speaker's decision of starting to utter the NP. In Experiment 3, we further explore whether the phonological properties of the lexical node of the second element of the NP affect the onset of articulation.

Experiment 3: Phonological effects in the production of compound NPs

In this experiment we explore whether a phonological relationship between the two nouns of a compound NP affects naming latencies. We manipulate whether the names of the two pictures included in each pair share part of their initial segmental information. Two different sets of picture pairs were constructed: phonologically related pairs (e.g., "the fish and the fist"), and phonologically unrelated pairs (e.g., "the fish and the belt").

Previous research has shown that when speakers repeat items that share their first segments, naming latencies are slowed down, in comparison to when they repeat unrelated items. For example, Sevald and Dell (1994) asked participants to repeat as fast as possible, during a 4 seconds time period, a sequence of items that started with the same phonemes "pick pin" or with different phonemes "pick ton". The results showed that participants produced more syllables per second in the unrelated condition than in the related condition⁸. Given this result, and if the phonological properties of the second element of the NP are available before articulation onset, one may expect a phonological relationship between the two nouns (e.g., "the fish and the fist") to slow down naming latencies⁹.

The predictions of this experiment parallel those of Experiment 1. If speech onset is triggered before the phonological properties of the second noun of the NP are activated, then a phonological relationship between the two object names should be irrelevant for predicting speech onset. However, if the phonological properties of the second noun of the NP are activated to some extent before articulation is triggered, then a phonological relationship between the two nouns of the NP may affect naming latencies. As in the case of Experiment 1, a phonological relationship between the two nouns of the NP may have an impact in the retrieval of the phonological properties of either the first or second element of the NP.

Method

Participants: Twenty-five participants from the same population as in Experiment 1 took part in this experiment. None of them had participated in the previous experiments.

Materials: Forty-four pictures of common objects were selected for this experiment (see Appendix C). The design of this experiment mimics that of Experiment 1. The only difference is that in the related condition the picture names were phonologically related rather than semantically related. Each target stimuli contained two pictures. In half of the trials, the two picture names shared at least their first two phonemes (the phonologically related condition), while in the other half they were unrelated (the unrelated condition). The names of the pictures included in each pair had similar word frequencies and were semantically unrelated. The pairing procedure led to 22 phonologically related pairs and 22 unrelated pairs. All other details were identical to those of Experiment 1.

Results and Discussion

Following the same criteria as in Experiment 1, 13.1% of the data points were scored as errors (see Table III). There were no differences in the error analyses (all $ps > .2$). In the analysis of naming latencies, the main effect of the phonological relatedness variable was non-significant (both F 's < 1). Naming latencies were statistically identical for the phonologically related and unrelated conditions (728 vs. 726 respectively). These results show that naming latencies in the production of compound NPs are independent of whether the two nouns share some phonological properties (their first segments). This suggests that the onset of articulation is independent of the phonological properties of the second element of the NP.

TABLE III
Naming Latencies (ms.), standard deviations and error rates, by Type of pairing (phonologically related, phonologically unrelated) in Experiment 3
Latencias de denominación (en ms.), desviaciones estándar y porcentaje de errores por tipo de emparejamiento (fonológicamente relacionado, fonológicamente no relacionado) en el experimento 3

Type of pairing	Mean	SD	E%
Phonologically Related (e.g., "the mouth and the mountain")	728	114	12.6
Phonologically Unrelated (e.g., "the mouth and the button")	726	117	13.6
Phonological Effect (Related-Unrelated)	2		1.0

General Discussion

In this study we aimed at exploring some aspects related to the size of planning units in speech production in the context of the production of compound NPs. Three experiments in which participants produced compound NPs of the type "the dog and the car" were conducted. We explored the extent to which naming latencies depended of some properties of the second element of the NP. In Experiment 1, participants' responses were slower when the two nouns were semantically related than when they were unrelated. In Experiment 2, the word frequencies of the first and second nouns of the NP were orthogonally manipulated. Participants' responses were affected by the frequency value of the first noun of the NP. However, naming latencies were independent of the frequency value of the second noun of the NP. Finally, in Experiment 3 naming latencies were independent of whether the two nouns were phonologically similar or not.

The results of Experiment 1 suggest that the processing of the second element of the NP has started before articulation commences (see Meyer, 1996; and Smith & Wheeldon, 1999). This is because for a semantic relationship between the two nouns of the NP to affect speech latencies, the speaker needs to have had access, at least, to the semantic representation of both nouns of the NP. However, it would be premature to conclude that this effect reveals that participants retrieve the lexical node of the second element of the NP before articulation is triggered. This is because, as we argued in the discussion of Experiment 1, a semantic interference effect may have arisen as a consequence of either a difficulty in selecting the lexical node of the second noun of the NP or in deciding which semantic representation

needs to be lexicalized first and which one needs to be lexicalized second. On the assumption that the decision of which semantic representation needs to be prioritised for lexicalization may be hampered by the concurrent activation of a semantically similar representation, then the observed semantic interference may be located at the retrieval of the semantic representation of the first or the second element of the NP. Strictly speaking, this result does not tell us whether naming latencies depend on the ease with which the linguistic properties of the second object of the NP are processed. Nevertheless, this effect reveals an important point: before speech is triggered, the speaker has access to the semantic representation of second object of the NP, and the properties of this representation may affect naming latencies.

Is there any evidence suggesting that naming latencies are affected by other linguistic properties of the second element of the NP? The results of Experiment 2 and 3 speak to this issue, and they suggest that speech onset latencies are independent of the availability of these properties. This conclusion is supported by the fact that naming latencies are independent of (a) the frequency value of the second noun of the NP (Experiment 2), and (b) the phonological relationship between the two nouns of the NP (Experiment 3). These two results are consistent with several reports in the literature. For example, our observations fit well with the results reported by Griffin (2001), in which neither word-frequency nor name agreement values of the second element of a compound NP affected sentence naming latencies. Also, the lack of phonological effects in our Experiment 3 corroborates Meyer's findings in the picture-word interference paradigm (Meyer, 1996).

However, these results appear also inconsistent with other experimental evidence that suggests that the availability of the linguistic properties of the second element of the NP affects naming latencies. Meyer (1996) obtained a semantic interference effect for distractor words related to the second element of a compound NP, and concluded that a delay in the selection of the lexical node of the second element of the NP results in a delay of speech onset. Nevertheless, our results may not be as inconsistent as it looks like at first sight. Although the preferred interpretation given by Meyer to this semantic interference effect was in terms of a delay in the selection of the lexical node of the second element of the NP, she also put forward an alternative explanation that locates such an effect at the semantic level. In fact, the "semantic" explanation given to the results of our Experiment 1 can also be applied to Meyer's observation. It is possible that the semantic interference effect observed in the picture-word interference paradigm stems from a delay in selecting the semantic representation of the second (or the first) element of the NP rather than in selecting its lexical node. That is, the selection of the conceptual representation of the second (or first) element of the NP, may be slowed down by the concurrent presentation of a semantically related distractor word, leading to slower naming latencies (see Costa et al., in press; for a discussion of this issue).

Where does all of this leave us? There is an empirical generalization that one can extract from all of these studies in which compound NPs have been used. It is only when manipulating semantic properties of the second element of the NP that naming latencies are also affected. That is, both in our Experiment 1, and in Meyer's (1996) experiments, a manipulation of the availability of the semantic representation of the second noun of the NP affected naming latencies. However, when manipulating the availability of: a) the lexical representation of the second element of the NP (as in our Experiment 2, or in Griffin's, 2001, experiments) or b) its phonological representation (as in our Experiment 3 and in Meyer's, 1996, study), speech onset times remain invariably.

Thus, given these results one may be tempted to conclude that speakers start their speech (at least in the case of utterances tested in these studies) without having retrieved the linguistic properties of the second element of the NP. That conclusion would imply that speakers lexicalize the second element of the NP (they retrieve the lexical node and its phonological properties) while articulating the first part of the NP (see Levelt & Meyer, 2000, for a similar argument). In other words, although speakers may have information regarding the conceptual representation of the two elements of the NP before articulation starts, the lexicalization processes for the second element may be triggered just before speech onset is initiated. In such a framework, lexical access in speech production is quite incremental, in the sense that speakers could proceed with articulation having accessed just a simple phrase (e.g., “the dog”). Nevertheless, caution must be exercised when interpreting these results in such a way because of two important caveats.

The first caveat concerns the generalizability of the present results to other utterance formats and to other naming conditions. Some authors have argued that the size of the planning units in speech production may be variable (Alario et al., 2002b; Ferreira & Swets, 2002; Levelt, 2002; Meyer, 1996), and that such a size may depend, among other things, on speech rate and on the complexity of the syntactic (and phonological) structure being planned by the speaker. In the experiments conducted here, the syntactic structure of the utterances was relatively simple and kept constant during the whole experiment. This situation may have helped or induced participants to develop a radically incremental processing in which only the elements of the first NP are processed lexically before articulation is triggered. In different circumstances, one might observe that the amount of planning is different. Consider, for example, Ferreira and Swets' (2002) study. These authors observed that the amount of planning carried out by the participants before speech onset was, to some extent, affected by whether participants were asked to produce the utterances under time pressure or not. The authors argued that these results suggest that the size of the planning units in speech production may be, to a certain degree, under participants' strategic control. Clearly, further research is needed to assess the factors (syntactic structure of the utterance, speech rate, etc.) and conditions that affect the amount of planning carried out by the speakers.

The second caveat refers to the validity of some of the crucial assumptions embraced in this type of research. When interpreting our results (and other results of this sort) we have assumed that speech onset times can inform us about the amount of planning at one level of representation. We have further assumed that a positive result in any of our experiments reveals that some properties of the second element of the NP are computed before articulation is triggered. This line of reasoning commonly adopted in studies addressing the issue of incrementality can be stated in the following way: If there is an effect of the availability of one element in naming latencies then we can conclude that such an element has been computed at a given level of representation; if there is no effect, then we can conclude that such an element has not been computed. But, can we safely conclude that a lack of effect (as reported in our Experiments 2 and 3, or in Griffin's and Meyer's studies) reveals that some properties of the second element of the NP have not been computed before articulation is triggered? We think that a conclusion of this sort is only granted in the context of other assumptions about the dependency between the retrieval mechanisms of different elements in the utterance¹⁰.

A conclusion of this sort can only be valid if we assume that the availability of the second element of the compound NP necessarily has an impact on

naming latencies. Such an assumption can be based on either of the two following principles: a) the criteria to release speech considers whether the second noun has been processed at a given level of representation, or b) the ease with which the second element is processed at a given level of representation affects the ease with which the first noun is processed at that (or at another) level of representation. However, neither of these two principles need to be necessarily correct. If indeed, the criteria to trigger speech does not consider how advance the processing of the second element of the NP is, or the resources devoted to the processing of the two nouns of the NP are independent, then the lack of an effect in our experiments (as well as in Griffin, 2001; and in Meyer, 1996) cannot be interpreted as revealing that speakers' start their articulation *without having processed* the second element of the NP linguistically.

Thus, although the observation of an effect at a given level indicates that the corresponding item has been processed at that level before articulation starts; the absence of an effect for a given item at a given level indicates either that such an element has not been processed before articulation starts, or that its processing has no direct impact for the release of articulation. The latter case is possible if, for example, the retrieval of the properties of the item at that level do not share their processing resources with the processes devoted to the release of earlier elements of the utterance¹¹.

Conclusion

To conclude, the results reported in this article suggest that the linguistic properties of the second element of the NP do not necessarily affect naming latencies, therefore the speakers decision of when to start articulation may be independent of whether such an element has been lexicalize or not. This conclusion supports the view that the encoding of different parts of the utterance is relatively independent of each other, and that articulation may start as soon as the first noun of a compound NP is available for production (e.g., Griffin, 2001; Levelt & Meyer, 2000 but see Meyer, 1996; Smith & Wheeldon, 1999). A different issue, for which we do not have a clear response yet, is whether regardless of such a dependency, latter parts of the utterance are already available and buffered before articulation starts.

Notes

¹ A phonological word is a unit of phonological encoding that comprises a content word plus the function words that "attach" to it – the phonological word (Ferreira, 1993; Ferreira & Swets, 2002; Lahiri, 2000; Levelt, 1989; Levelt, Roelofs, & Meyer, 1999; Selkirk, 1984; Wheeldon & Lahiri, 1997; see also Nespor & Vogel, 1986, for a definition of phonological words in terms of stress values).

² These results further suggest that participants start their articulation before the whole clause has been processed, otherwise naming latencies should be similar for the two types of sentences (see also Wheeldon and Lahiri, 1997, for a similar study looking at phonological complexity).

³ Meyer, Sleiderink and Levelt (1998), also explored the size of the planning unit in the production of compound NPs (e.g., "the car and the arrow"). These authors recorded the time speakers spent looking at the two pictures of the scene. The most important result for our discussion here is that participants started looking at the second object before articulation commenced (262 ms), suggesting that the processing of the second element of the NP had started before the triggering of articulation. The authors also observed that the time spent looking at the first picture, before gazing to the second object, depended on the frequency of its name. And under the assumption that word frequency effects are located at the level at which the phonological code of the noun is retrieved (e.g., Jescheniak and Levelt, 1994; but see Dell, 1990; and Caramazza, Costa, Miozzo & Bi, 2002), they concluded that speakers access the phonology of the first noun of the NP before they gaze to the second object in the scene (see similar results in van der Muelen and Meyer; 2001).

⁴ In this study the time that participants spent looking at the pictures before articulation started was also recorded. The time spent looking at the first object only correlated with the frequency of its name. Furthermore, although participants gazed at object B for 212 ms before the onset of articulation, neither its name agreement nor its word frequency affected how much time they spent looking at it before articulation was triggered.

- ⁵ Notice however, that this result could be compatible with Meyer's (1996) conclusions if one locates the frequency effect at the level at which lexical nodes are retrieved during grammatical encoding, since at that level all the elements of a simple NP are retrieved before articulation is triggered.
- ⁶ There are some indications that a semantic relationship between two pictures may lead to semantic interference. Glaser and Glaser (1989) used a paradigm that is slightly different from the one used here. In their experiment, participants were asked to name a picture while ignoring the presentation of a distractor picture. Semantic interference was observed when there was a semantic relationship between the two pictures, but only if they were presented at short stimulus onset asynchrony (S.O.A.'s of -75 ms to 100 ms). The paradigm used in our experiments differs from that used by Glaser and Glaser (1989) in many relevant respects, such as the fact that participants have to name the two pictures (rather than just one), that the pictures are presented simultaneously, and that the first picture to be named is always the one presented on the left side of the scene. Thus, although a semantic context, if something, is likely to produce interference, it would also be possible to observe some semantic facilitation (see also Morsella & Miozzo, 2002; and Bloem & La Heij, in press).
- ⁷ For those models in which the lexical level is implemented by two layers of representation (the lemma and the lexeme layers), word frequency may, in principle, be located at any of them (e.g., Dell, 1991). It is an open question at which of these levels word frequency is supposed to affect processing (see Bonin & Fayol, 2002; Caramazza, et al., 2002; and Jescheniak & Levelt, 1994 for a discussion). Nevertheless, what is important for our purposes here is that in these models, word frequency is a property affecting the retrieval of lexical nodes.
- ⁸ Sevald and Dell's result was obtained in a repetition-from-memory task in which participants had to repeat many times the same two items from memory, therefore producing something very much like a tongue twister. The extent to which interference will be present in a more natural task in which participants do not need to repeat the names of the objects in a single trial remains to be seen.
- ⁹ As noted in the Introduction, there are two other experimental results suggesting that the ease with which latter parts of a NP are phonologically encoded affect the onset of articulation. The first comes from the study conducted by Costa and Caramazza (2002), in which participants were asked to produce a complex NP of the type "the red car" while ignoring the presentation of a distractor word that was phonologically related or unrelated to the noun of the NP. Naming latencies were faster when the distractor word was phonologically related to the noun than when it was unrelated, suggesting that by affecting the availability of the phonological properties of the last element of the NP, naming latencies were also affected. The second result comes from Meyer (1996), where participants were asked to produce compound NPs (e.g., "the arrow and the bag"). In this case, a phonologically related distractor produced a non-significant trend towards interference. Meyer tentatively interpreted this result as revealing that an increase in the activation of the phonological properties of the second noun of the NP, produced by the presentation of the related distractor word, may have interfered with the encoding of the phonological properties of the first noun of the NP.
- ¹⁰ The issue discussed here is not about the possibility that the absence of effect is due to a statistical error of Type 1, where an existing effect was not revealed in the experimental results.
- ¹¹ Is there any other evidence suggesting that speakers start the production of the NP without having processed the second noun of the NP, and that is not subject to this same caveat? We do not think so. For one thing, those studies in which no effects of the second noun of the NP have been observed in naming latencies (e.g. Griffin, 2001) may have the same alternative accounts as those of our experiments. The studies in which looking times have been explored do not seem to be much more useful to answer this question either. Consider, for example, the results of Meyer et al. (1998) in which the time participants spent looking at the first object before shifting their gaze to the second object depended on the word frequency of the first noun. That result could be interpreted as suggesting that the lexical node (or even the phonological code) of the first element of the NP has been retrieved before the speaker pays attention to the second object. Furthermore, given that the gaze was directed to the second element about 200 ms before speech onset, one may be tempted to conclude that articulation started without the speaker having much knowledge of the lexical properties of the second noun of the NP. However, this interpretation hinges on a very strong assumption for which we do not seem to have much evidence. The assumption is that the initiation of the looking time for the second element of the NP signs the beginning of the processing of such an element (starting with its recognition) (e.g., Levelt & Meyer, 2000). If that were to be the case, then it would be reasonable to conclude that in the 200 ms that speakers gazed at the second element of the NP before articulation starts, not much linguistic processing of such an element has been carried out. But, how do we know that speakers do not have access to some properties of the second element of the NP before gazing at it, and may therefore start its processing before those 200 ms? It is possible that by the time speakers start gazing to the second object, the processing of such an element has already started. That is, the speaker may have some information about the second element of the NP that allows him/her to start its processing even before fixating their gaze on it. In fact the observations made by Griffin and Bock (2000) suggest that this is the case, and that participants may extract relatively accurate semantic information of objects for which they have not yet fixed their gaze. Thus, if speakers can extract semantic information of the second object, they could start lexicalizing such an element.

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Appendix A

Materials used in Experiment 1

Semantically related			Semantically unrelated		
item N	Left picture	Right picture	item N	Left picture	Right picture
1	apple	banana	1	apple	pipe
2	banana	apple	2	banana	cigar
3	pipe	cigar	3	pipe	apple
4	cigar	pipe	4	cigar	banana
5	arm	foot	5	arm	flower
6	foot	arm	6	foot	island
7	island	mountain	7	island	foot
8	mountain	island	8	mountain	table
9	flower	tree	9	flower	arm
10	tree	flower	10	tree	horse
11	bed	table	11	bed	car
12	table	bed	12	table	mountain
13	car	plane	13	car	bed
14	plane	car	14	plane	bomb
15	bomb	gun	15	bomb	plane
16	gun	bomb	16	gun	church
17	bottle	cup	17	bottle	ear
18	cup	bottle	18	cup	nose
19	church	house	19	church	gun
20	house	church	20	house	train
21	boat	train	21	boat	dog
22	train	boat	22	train	house
23	dog	horse	23	dog	boat
24	horse	dog	24	horse	tree
25	ear	nose	25	ear	bottle
26	nose	ear	26	nose	cup
27	broom	rake	27	broom	shirt
28	rake	broom	28	rake	couch
29	shirt	coat	29	shirt	broom
30	coat	shirt	30	coat	fork
31	couch	stool	31	couch	rake
32	stool	couch	32	stool	violin
33	violin	trumpet	33	violin	stool
34	trumpet	violin	34	trumpet	plate
35	plate	fork	35	plate	trumpet
36	fork	plate	36	fork	coat
37	carrot	tomato	37	carrot	vest
38	tomato	carrot	38	tomato	squirrel
39	duck	squirrel	39	duck	scarf
40	squirrel	duck	40	squirrel	tomato

Appendix B

Materials used in Experiment 2 (HF = high-frequency; BF = low-frequency)

HF-HF		HF-LF		LF-HF		LF-LF		
item N	left pict.	right pict.	left pict.	right pict.	left pict.	right pict.	left pict.	right pict.
1	Ball	Mouth	ball	dagger	dagger	ball	trunk	dagger
2	Mouth	Ball	mouth	trunk	trunk	mouth	dagger	trunk
3	Bomb	Piano	bomb	kettle	kettle	bomb	scarf	kettle
4	Piano	Bomb	piano	scarf	scarf	piano	kettle	scarf
5	Bottle	Snake	bottle	comet	comet	bottle	waiter	comet
6	Snake	Bottle	snake	waiter	waiter	snake	comet	waiter
7	Box	Chair	box	castle	castle	box	helmet	castle
8	Chair	Box	chair	helmet	helmet	chair	castle	helmet
9	Bread	Moon	bread	canon	canon	bread	toe	canon
10	Moon	Bread	moon	toe	toe	moon	canon	toe
11	Bridge	Cup	bridge	dwarf	dwarf	bridge	arch	dwarf
12	Cup	Bridge	cup	arch	arch	cup	dwarf	arch
13	Cat	Gun	cat	vest	vest	cat	couch	vest
14	Gun	Cat	gun	couch	couch	gun	vest	couch
15	Coat	Train	coat	skunk	skunk	coat	flute	skunk
16	Train	Coat	train	flute	flute	train	skunk	flute
17	Column	Flower	column	blimp	blimp	column	statue	blimp
18	Flower	Column	flower	statue	statue	flower	blimp	statue
19	Desk	Hat	desk	broom	broom	desk	cactus	broom
20	Hat	Desk	hat	cactus	cactus	hat	broom	cactus
21	Doctor	Ship	doctor	skull	skull	doctor	lamp	skull
22	Ship	Doctor	ship	lamp	lamp	ship	skull	lamp
23	Eye	House	eye	doll	doll	eye	carrot	doll
24	House	Eye	house	carrot	carrot	house	doll	carrot
25	Key	Painting	key	duck	duck	key	chimney	duck
26	Painting	Key	painting	chimney	chimney	painting	duck	chimney
27	Shoe	Woman	shoe	ladle	ladle	shoe	crane	ladle
28	Woman	Shoe	woman	crane	crane	woman	ladle	crane

Appendix C

Materials used in Experiment 3

Phonologically related			Phonologically unrelated		
item N	Left picture	Right picture	item N	Left picture	Right picture
1	balloon	banana	1	balloon	cannon
2	banana	balloon	2	banana	camel
3	camel	cannon	3	camel	banana
4	cannon	camel	4	cannon	balloon
5	belt	bench	5	belt	fish
6	bench	belt	6	bench	fist
7	fish	fist	7	fish	belt
8	fist	fish	8	fist	bench
9	butter	button	9	butter	mountain
10	button	butter	10	button	mouth
11	mountain	mouth	11	mountain	butter
12	mouth	mountain	12	mouth	button
13	candle	candy	13	candle	rabbit
14	candy	candle	14	candy	racquet
15	rabbit	racquet	15	rabbit	candle
16	racquet	rabbit	16	racquet	candy
17	cane	cave	17	cane	pig
18	cave	cane	18	cave	pill
19	pig	pill	19	pig	cane
20	pill	pig	20	pill	cave
21	cap	cat	21	cap	net
22	cat	cap	22	cat	nest
23	nest	net	23	nest	cat
24	net	nest	24	net	cap
25	carriage	carrot	25	carriage	hammock
26	carrot	carriage	26	carrot	hammer
27	hammer	hammock	27	hammer	carrot
28	hammock	hammer	28	hammock	carriage
29	chain	chair	29	chain	tape
30	chair	chain	30	chair	tail
31	cradle	crater	31	cradle	sandwich
32	crater	cradle	32	crater	sandal
33	sandwich	sandal	33	sandwich	cradle
34	sandal	sandwich	34	sandal	crater
35	tail	tape	35	tail	chair
36	tape	tail	36	tape	chain
37	hood	hook	37	hood	skunk
38	hook	hood	38	hook	skull
39	skull	skunk	39	skull	hook
40	skunk	skull	40	skunk	hood
41	rope	rose	41	rope	witch
42	rose	rope	42	rose	whip
43	whip	witch	43	whip	rose
44	witch	whip	44	witch	rope