Research Report

A Word-Order Constraint on Phonological Activation

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ABSTRACT—*Word-order rules impose major constraints on linguistic behavior. For example, adjectives appear before nouns in English, and after nouns in French. This means that constraints on word order must be language-specific properties upheld on-line by the language system. Despite the importance of these rules, little is known about how they operate. We report an influence of word order on the activation of phonological representations. Participants were presented with colored objects and asked to name either the colors or the objects; the phonological similarity between the object and color names was manipulated. French speakers showed a phonological congruency effect in color naming, but not in object naming. English participants yielded the opposite pattern: a phonological effect in object naming, but not in color naming. Differences in the typical order of nouns and adjectives in French and English provide a plausible account for this cross-linguistic contrast. More generally, these results provide direct evidence for the operation of word-order constraints during language production.*

Many languages impose constraints on the order in which words from various grammatical classes appear in a sentence. Compare, for example, English and French noun phrases, such as *blue car* versus *voiture bleue*. As these phrases illustrate, adjectives appear before nouns in English, but typically appear after nouns in French. This example suggests that constraints on word order are language-specific properties upheld on-line by the language system. Within the field of language production, relatively little research has been dedicated to understanding word-order constraints (some exceptions are Bates, Friederici, Wulfeck, & Juarez, 1988; Bock, 1987; Cleland & Pickering, 2003; Dell & Reich, 1981; Garrett, 1976; Hartsuiker & Westenberg, 2000; Janssen, 2005). In this article, we report a study in which we investigated how word order influences the activation of phonological representations.

The prevalent view in language-production models is that phonological representations are activated by means of a cascading flow of activation from the lexical level: As soon as a lexical representation is activated, its corresponding phonological representations are activated (see Goldrick, 2006, for a review; but see Levelt, Roelofs, & Meyer, 1999). The phonological congruency effect demonstrated by Morsella and Miozzo (2002) was interpreted as supporting this hypothesis. These authors observed that naming a target picture (e.g., *dog*) in the context of a distracting, not-named picture is faster if the distractor's name (e.g., *doll*) is phonologically congruent with the target's name than if it is incongruent (e.g., *bell*). These results follow from the assumption that the activation of the context picture's name cascades to its phonological representations. When the context and target phonological representations are congruent, those representations are activated and selected more quickly (Goldrick, 2006, and references therein; see also Meyer & Damian, 2007; Morgan & Meyer, 2005; but see Bloem & La Heij, 2003).

This unregulated-cascading hypothesis states that any active word representation will activate its phonological representations. This simple view is problematic for multiword production, however, because many target words that will ultimately be produced are active concurrently. Under such circumstances, it is not obvious how a particular target word's phonological representations can be distinguished from the phonological representations activated by the other target words. One solution is to assume that activation of phonological representations is constrained by the linear relationships among lexical items. For example, if word order constrains phonological activation, then at any point in time, phonological representations of earlier words receive stronger activation than those of later words (e.g., Dell, 1986). Evidence for this hypothesis is scarce. Some results consistent with it were reported in studies using the picture-word interference paradigm to investigate the scope of phonological encoding during multiword production. For

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example, Jescheniak, Schriefers, and Hantsch (2003) observed that phonological priming effects were modulated by word position. This was taken as evidence for graded phonological activation of the words composing the target utterance (see also Costa & Caramazza, 2002; Damian & Dumay, 2007; Dell, Burger, & Svec, 1997; Meyer, 1996). Consider in this context the two noun-phrase examples given earlier. If word order constrains phonological activation, then the canonical word order will initially lead to greater activation of adjective than noun phonology in English, and the opposite pattern in French.

Navarrete and Costa (2006) extended the evidence in support of a cascading flow of activation to the situation in which an adjective and a noun are active concurrently. In their study, Spanish participants named the color of colored objects faster when the phonological onsets of the color and object names were congruent (e.g., *v*ela *v*erde, "green candle") than when they were incongruent (e.g., *v*ela *a*zul, "blue candle"). In Spanish, nouns typically appear before adjectives. The hypothesis that word order modulates phonological activation explains this phonological congruency effect in adjective naming by assuming early activation of the noun. This hypothesis further predicts that naming of object nouns in languages with noun-adjective word order, such as Spanish, should not be influenced by the phonology of color adjectives. This is because the activation of noun phonology should precede the activation of adjective phonology.

We tested this prediction in Experiment 1, in which French speakers named either the color of an object or the object itself. In French, as in Spanish, object nouns typically appear before color adjectives. The word-order-modulation hypothesis predicts a phonological facilitation effect for adjectives, but not for nouns. Finding similar phonological effects for nouns and adjectives would be evidence against the hypothesis.

EXPERIMENT 1: COLOR AND OBJECT NAMING IN FRENCH

Method

Participants

Thirty-two native speakers of French participated in this experiment. Half of them performed the color-naming task, and half the object-naming task. All were students at the Université de Provence, France. They received course credit for participation.

Materials and Design

Four colors (red, green, blue, and orange) were used. For each color, we selected seven pictures (Alario & Ferrand, 1999) that shared at least the onset consonant with the color name. These color-object pairings were used for the congruent condition. The incongruent condition was created by re-pairing all pictures having a given onset with a particular color whose name had a different onset (e.g., all "r" pictures were re-paired with the same nonred color), so that picture names and color names did not overlap in phonology (see Table 1 for a list of the object names). Thus, there were 56 experimental items. An additional set of 56 filler items was created by pairing a set of 28 pictures with two different color names that did not overlap with the object names in phonology. Thus, overall, there were 28 congruent and 84 incongruent trials. Finally, eight of the filler items used in the experiment proper were also used during training. The original pictures were black line drawings on a white background; they were transformed into colored pictures by coloring the outline with one of the four designated colors.

Items were pseudorandomly ordered within four blocks of trials. Each block consisted of an equal number of experimental

TABLE 1
Names of the Stimulus Objects

Experiment 1	Experiment 2
râteau ("rake")	rabbit
règle ("ruler")	rake
renard ("fox")	racket
requin ("shark")	rocket
robe ("dress")	ruler
robinet ("sink")	rat
roue ("wheel")	rope
ballon ("balloon")	record
banc ("bench")	ring
barbecue ("barbecue")	road
bougie ("candle")	broom
bouteille ("bottle")	bow
bouton ("button")	barn
bureau ("desk")	barrel
vache ("cow")	bike
valise ("suitcase")	bottle
vase ("vase")	bear
verre ("glass")	bed
violon ("violin")	ball
vis ("screw")	book
voiture ("car")	glove
œil ("eye")	giraffe
oignon ("onion")	guitar
oiseau ("bird")	grave
orange ("orange")	globe
oreille ("ear")	ghost
orteil ("toe")	glasses
ours ("bear")	goat
	gun
	glass
	paddle
	pitcher
	parrot
	peanut
	plug
	pear
	pen
	pants
	pig
	pipe

and filler trials, with each picture appearing once, and the different colors appearing an equal number of times. The same color never appeared on consecutive trials, and neither did pictures with a semantic or phonological relationship. There were never more than three items from the same condition in a row. The order of the blocks was counterbalanced following a Latin-square design.

Procedure

Participants sat in front of a computer with an attached microphone and performed either the object- or the color-naming task. The experimental software was DMDX (Forster & Forster, 2003). For both tasks, participants first were familiarized with the objects and their names. On each trial, they saw a sequence consisting of a fixation cross (700 ms), a blank screen (200 ms), a picture (1,000 ms), and finally the picture with its name (1,000 ms). The appearance of the picture name cued participants to name the picture aloud. Participants in the color-naming task were then told the four color names that would be used in the subsequent two phases. After familiarization, participants were trained and then performed the experiment proper. These two phases had identical trial structures: a fixation cross (700 ms), followed by a blank screen (200 ms), followed by a picture of a colored object (1,500 ms). Depending on the instructions, participants named the object or the color (with the adjective unmarked for grammatical gender) upon picture presentation. There were eight trials in the training phase. The experiment lasted 25 min.

Results

We report the results for color and object naming separately. Trials with errors, nonvocal responses, and no responses were discarded from the analysis. Reaction times (RTs) more than 3 standard deviations above or below a given participant's mean were also discarded. There was one main factor in each analysis: phonological congruency (congruent vs. incongruent). Participants (t_1) and items (t_2) were random factors. Table 2 presents an overview of the data.

TABLE 2
Mean Reaction Times (in Milliseconds) and 95% Confidence Intervals (CIs) in Experiments 1 and 2

	Condition			
Experiment and task	Congruent	Incongruent	Difference	95% CI
Experiment 1: French				
Color naming	595 (2.9)	622 (3.8)	27	11
Object naming	660 (4.0)	664 (4.2)	4	9
Experiment 2: English				
Color naming	616 (3.2)	619 (4.3)	3	6
Object naming	689 (3.7)	705 (3.3)	16	6

Note. Error rates are given in parentheses.

Color Naming

Before analysis, 3.3% of the trials were discarded. The RT analysis revealed a main effect of congruency, $t_1(15) = 3.43$, $p < .004$, $p_{rep} = .971$, $d = 1.77$; $t_2(27) = 2.86$, $p < .004$, $p_{rep} = .963$, $d = 1.10$. RTs were shorter in the congruent condition than in the incongruent condition. There was no effect of congruency in the error analysis (both ts < 1).

Object Naming

Before analysis, 4.1% of the trials were discarded. Neither RTs nor errors revealed an effect of congruency (all ts < 1).

Discussion

We found a phonological congruency effect in color naming (see Navarrete & Costa, 2006), but not in object naming. These results are consistent with the assumption that word-order constraints modulate the activation of phonological representations. This assumption predicts a phonological congruency effect in color naming, but not in object naming, in languages with a noun-adjective word order. However, an alternative, nonlinguistic interpretation is possible. The results could have been due to differences in the speed of processing objects and colors, which, in turn, could have led to differences in how fast the phonology of object and color names was activated. If the phonology of the object name was activated faster than the phonology of the color name, then the activation of the object name's phonology would have affected color naming; object naming would not have been affected by the color name's phonology, which would have been activated more slowly and therefore too late. Note, however, that although object-naming latencies were overall slower than color-naming latencies (Table 2), this does not necessarily exclude the possibility that phonological activation was faster for object names than for color names.

In Experiment 2, we put this alternative hypothesis to a test with native English speakers. In English, color adjectives appear before nouns—the opposite of the order in French. If the results of Experiment 1 were due to language-independent processing speeds of color and object names, then the same pattern of phonological congruency effects would be expected in English speakers. Alternatively, if the results of Experiment 1 were due to the influence of language-specific word-order constraints, then the opposite pattern would be expected: a phonological congruency effect in object naming, but not in color naming.

EXPERIMENT 2: COLOR AND OBJECT NAMING IN ENGLISH

Method

Participants

Thirty native speakers of English participated in the experiment. Half performed the color-naming task, and half the object-naming task. All were students at Harvard University and received course credit for participation.

Materials, Design, and Procedure

The design and procedure were the same as in Experiment 1. The four colors were red, green, blue, and pink. Each color was paired with 10 pictures (see Table 1), for a total of 80 experimental items. An additional 80 filler items were created as in Experiment 1. Thus, overall there were 40 congruent and 120 incongruent trials.

Results

The analytical methods were the same as in Experiment 1. Table 2 presents an overview of the data.

Color Naming

Before analysis, 3.8% of the trials were discarded. The RT analysis revealed no effect of congruency on color naming (both ts < 1), and neither did the error analysis, $t_1(14) = 1.1, p = .31, p_{rep} = .739, d = 0.59; t_2 < 1$.

Object Naming

Before analysis, 3.5% of the trials were discarded. The RT analysis revealed an effect of congruency, $t_1(14) = 3.20, p < .007, p_{rep} = .960, d = 1.71; t_2(39) = 3.18, p < .003, p_{rep} = .980, d = 1.02$. RTs were shorter in the congruent condition than in the incongruent condition. There was no effect of congruency in the error analysis (both ts < 1).

Discussion

In contrast to Experiment 1, Experiment 2 showed a phonological congruency effect for object naming, but not for color naming. This rules out the possibility that the results of these experiments are due to nonlinguistic differences in the retrieval speed of object- and color-name phonology. If such were the case, the same pattern of phonological congruency effects should have been observed in the two experiments. The alternative word-order hypothesis provides a plausible account of the contrasting results in French and English, based on a clear contrastive property that differentiates these two languages.

Could other language-specific properties be responsible for the results? Lexical properties are unlikely candidates. The ratios of adjective lexical frequency to noun lexical frequency for experimental items were similar in the two experiments ($M = 20$ in French and 15 in English), $t(134) < 1$), as were the ratios of the number of letters in adjectives to the number of letters in nouns ($M = 0.9$ in both French and English), $t(134) < 1$.

Another important difference between French and English noun phrases is that French noun phrases often require grammatical gender agreement, whereas English noun phrases never do (Corbett, 1991). Consider, then, the following scenario. If, in general, color names are retrieved faster than object names, this would explain the English data. Differences in the speed of color- and object-name retrieval would be reduced in languages with grammatical gender, however, because the agreement processes impose dependencies on adjective and noun retrieval. In French, the phonological form of an adjective depends on the grammatical gender of the corresponding noun. The faster processing of adjective phonology would be delayed until the gender of the corresponding noun is available. Although suggestive, this explanation does not accurately account for the pattern of results observed in Experiment 1. If the dependency of gender agreement brings the speed of color-name processing on a par with the speed of object-name processing, one would expect a phonological congruency effect in both color and object naming. Given that an effect was observed only for color naming, this explanation is unlikely (as is any explanation that equates the two activation speeds to honor agreement constraints).[1]

GENERAL DISCUSSION

In two experiments, participants were presented with colored objects, and the phonological congruence between the color and object name was manipulated. In Experiment 1, with French participants, a phonological congruency effect was found for color naming (see Navarrete & Costa, 2006), but not for object naming. In Experiment 2, with English participants, the opposite pattern of results was obtained: a phonological congruency effect for object naming, but not for color naming.

Language-independent processing speeds of colors and objects, or differences in the requirement for gender agreement in the noun phrase, cannot account for these results. Rather, we assume that language-specific word-order constraints modulate the phonological activation of color and object names when colored objects are presented. Specifically, given that nouns typically precede adjectives in French, the activation of noun phonology is initially favored over the activation of adjective phonology. Consequently, the activation of the object name's phonology primes color naming. Activation of the color name's phonology occurs later and therefore does not prime object naming. The opposite pattern of results was expected, and was observed, in English.

It is perhaps surprising that we demonstrated the phonological congruency effect even though participants were producing single words—adjectives or nouns—rather than complete noun phrases. This means that the word-order constraint we postulate is operational even for single-word utterances. This constraint could stem from the partial activation of a canonically ordered noun-phrase frame (e.g., Garrett, 1976), from word-order information present in the lexical representation of the items (e.g.,

[1]To further tease apart the individual contributions of word order and gender to our pattern of results, one could investigate the phonological congruency effect in color and object naming in a language that shares relevant word-order constraints with English and gender agreement with French (e.g., Dutch).

Levelt, 1989), or from statistically learned, biased mappings linking objects and colors to nouns and adjectives (e.g., Dell, Reed, Adams, & Meyer, 2000). For now, the results we report do not favor one of these possibilities over the others. They indicate that when multiple words are activated, the cascading activation of their phonological representations is modulated by language-specific word-order properties. This phenomenon provides some insight into how word order is used during language production.

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