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Now you see it . . . and now again: Semantic interference reflects lexical competition in speech production with and without articulation

Rasha Abdel Rahman and Sabrina Aristei
Humboldt-Universität zu Berlin, Berlin, Germany

Semantic interference effects in the picture–word interference (PWI) paradigm have long been assumed to reflect competitive mechanisms during lexical selection, a core component of the speech production system. However, recent observations of facilitative effects have cast doubt on the usefulness of the paradigm for investigating lexicalization, and on the existence of lexical competition in general. An alternative proposal suggests that lexical selection is not by competition, and that interference effects reflect articulatory processes outside the lexical system. Here, we contrast these theoretical alternatives with semantic distractor effects in the PWI paradigm. In two tasks, pictures were either overtly named or the names were manually classified. Interference effects of comparable magnitude were observed in both response modalities, regardless of whether the names were articulated or not. This finding supports lexical competition models and suggests that the articulators are not the source of interference in the PWI paradigm. Supplemental materials for this article may be downloaded from http://pbr.psychonomic-journals.org/content/supplemental.

Lexical access—the retrieval of words from the mental lexicon that convey the syntactic and phonological makeup for expressing preverbal communicative thoughts—lies at the very heart of human speech production. This process is generally assumed to entail the selection of a target lexical candidate from among coactivated alternatives (Caramazza, 1997; Dell, 1986; Levelt, Roelofs, & Meyer, 1999). For instance, upon naming a pictured object (e.g., *mouse*), activation spreads to the target and semantically related concepts (e.g., *cat*, *dog*, *cheese*, etc.), and all active concepts pass some activation to their lexical entries. As a result, not only the target lexical entry but also semantically related alternatives are active at the lexical level. Whether target selection demands are influenced by the state of activation of lexical alternatives is a central issue in speech production, and is currently a matter of intense debate.

According to one view, lexical selection is characterized by competition. Related nontarget entries (e.g., *cat*, *dog*) directly compete with the target utterance (*mouse*), thereby delaying lexical selection and the naming response (Abdel Rahman & Melinger, 2009a, 2009b; Belke, Meyer, & Damian, 2005; Bloem & La Heij, 2003; Damian & Bowers, 2003; Levelt et al., 1999; Roelofs, 1992, 2001, 2003). This theoretical position has received support from semantic interference effects observed in the picture–word interference (PWI) paradigm (e.g., Caramazza & Costa, 2000; Damian & Martin, 1999; Lupker, 1979; Lupker & Katz, 1981; Schriefers, Meyer, & Levelt, 1990; Starreveld & La Heij, 1995, 1996). In this paradigm, pictures are named in the presence of simultaneously presented word distractors that should be ignored. Related picture–word pairs (e.g., *mouse–dog*) induce longer naming latencies than do unrelated pairs (*mouse–table*). This semantic interference effect is assumed to reflect lexical competition: The coactivation of lexical alternatives during picture naming (e.g., the lexical competitor of *mouse–dog*) is enhanced by the presentation of semantically related words (e.g., "dog") because the words directly activate their lexical representations. This converging activation of lexical competitors from picture naming and word processing yields strong competition and, as a consequence, delayed lexical selection and longer naming times.

According to a second position, the response exclusion account, lexicalization is not a competitive process (Costa, Alario, & Caramazza, 2005; Finkbeiner & Caramazza, 2006; Janssen, Schirm, Mahon, & Caramazza, 2008; Mahon, Costa, Peterson, Vargas, & Caramazza, 2007). This view holds that target selection times are unaffected by the activation status of lexical alternatives. Semantic interference effects in the PWI paradigm, long taken as evidence for the existence of lexical competition, are supposed to reflect nonlexical mechanisms in articulatory motor programs that are generated late during speaking: Distractor words are assumed to have direct and privileged access to the articulatory output buffer, and this buffer forms a classic bottleneck stage that can be engaged with only one process at a time. Thus, the distractor word needs

R. Abdel Rahman, rasha.abdel.rahman@hu-berlin.de

to be removed from the output buffer before articulation of the target utterance can start, or, as Mahon et al. (2007) stated, "In order for the name of the target picture to be produced, motor relevant representations controlling the articulators must be disengaged from the distractor word" (p. 524). The time demands for this removal process are a function of the relevance of the distractor word for the task at hand. For instance, semantically unrelated words can be identified as response irrelevant faster than categorically related words that share many features with the target. Therefore, related words are removed more slowly from the output buffer than are unrelated words, resulting in a semantic interference effect. Furthermore, it is assumed that related words prime the target at the conceptual (Costa et al., 2005) or lexical (Mahon et al., 2007) level, thereby inducing facilitative, rather than inhibitory, effects. Thus, according to the response exclusion account, lexical selection is not competitive, and facilitation, rather than interference, is induced by semantically related words at the lexical level.

This view has likewise received support from the PWI paradigm. For instance, associatively related distractors (e.g., *mouse–cheese*; Abdel Rahman & Melinger, 2007; Alario, Segui, & Ferrand, 2000), distractors with a part–whole relation to the target (e.g., *bumper–car*; Costa et al., 2005), or semantically close distractors (e.g., *horse–zebra*; Mahon et al., 2007; but see Vigliocco, Vinson, Lewis, & Garrett, 2004) induce faster naming than do unrelated or semantically distant distractors.

In this article, we contrast the two alternative positions by exploring—yet again—classic categorical–semantic interference effects in the PWI paradigm. In one task, pictures of objects (e.g., *whale*) were overtly named in the presence of semantically related (*squid*) and unrelated (*throne*) distractor words. As discussed above, interference effects observed in this task can be accounted for by either competition at the level of lexical selection or, alternatively, by the single-channel bottleneck of the articulatory output buffer. In a second task, the identical pictures and related and unrelated distractor words were presented. However, here, participants were instructed to classify the last segment of the picture names by means of buttonpresses. This task involves conceptual, lexical, and morphophonological access, but does not involve articulatory processes. Differential predictions from the lexical competition and response exclusion accounts can be derived for a comparison of distractor effects in the two tasks.

If semantic interference effects reflect lexical competition, they should be observed not only when the picture names are articulated but also when the names are manually classified without overt articulation. This is because lexical selection is a basic component of each task, naming, and the name classification. Therefore, related distractors should induce lexical competition, and target selection latencies should be delayed, regardless of whether the names will ultimately be articulated or manually classified.

In contrast, the response exclusion account holds that interference reflects a bottleneck in the articulatory output buffer. Therefore, interference should be observed only in tasks that require overt articulation of the target utterance. If articulation is not required, distractors may or may not occupy the output buffer, without any consequences for performance of the task at hand. Therefore, interference should not be observed in the name classification task. Furthermore, semantically related distractors are assumed to yield priming-induced facilitation. This effect should be most prominent when the bottleneck stage of the articulatory output buffer can be bypassed in the classification task. Therefore, according to the response exclusion account, semantic interference effects are expected in the naming task, whereas facilitation should be observed in the name classification task.

METHOD

Participants

A total of 22 right-handed native German speakers (14 women; mean age = 22.3 years; range = 18–30) took part. All reported normal or corrected-to-normal vision. Informed consent was obtained from all participants before the experiments. One participant was replaced because of high error rates.

Materials

Picture stimuli consisted of 120 black-and-white line drawings of common objects. The names of half of the pictures ended with a vowel; the other half ended with a consonant. The size of the photographs was 3.5 × 3.5 cm at an approximate viewing distance of 90 cm from the monitor. A categorically related word, which was not part of the response set, was selected for each picture. The related words were reassigned to different pictures for the unrelated condition. Half of the words assigned to the pictures ending with a vowel or consonant in the related and unrelated conditions likewise ended with a vowel, and half with a consonant. Thus, with respect to the classification task, the response congruency between picture and distractor name (both ending with a vowel/consonant or not) was counterbalanced across pictures. We included this control because response congruency between picture and distractor name (e.g., both affording a response with the left index finger) may affect classification times in the manual task (for a related proposal, see Kuipers, La Heij, & Costa, 2006). Table S1 of the supplemental materials presents all pictures and distractor conditions. Distractors were presented visually, simultaneously with the pictures. The words were placed so as to have maximal integration without obscuring the visibility of the pictures. The relative position of related and unrelated distractors within each given picture was constant.

Procedure and Design

Stimulus presentation and response recording was controlled by Presentation software (Neurobehavioral Systems). Each trial began with a fixation cross displayed in the center of a light-gray screen. After 500 msec, the fixation cross was replaced by a picture–word pair (stimulus onset asynchrony = 0), which remained on the screen until vocal or manual response, with a maximal duration of 2 sec. The stimulus was followed by a blank screen for 1 sec. Participants were instructed to name or classify the picture name as fast and as accurately as possible. Vocal responses were recorded with a microphone and naming latencies were measured with a voice key. Naming accuracy and voice key functioning were recorded online by the experimenter. In the manual classification task, participants were instructed to perform a binary classification of the last letter of the picture name—which could be a vowel or a consonant—by means of buttonpresses with their left or right index finger. Accuracy was classified automatically. No instructions were provided regarding the distractor words. The order of tasks and the assignment of vowel or consonant to the right or left index finger were counterbalanced across participants. Each picture was presented four times, once in each task and distractor condition; the whole experiment included 480 trials. Picture presentation with related and unrelated distractors within each task was fully randomized for each individual participant. Prior to the experiment, participants saw printed sheets with all object pictures and their names printed below.

RESULTS

Mean response times (RTs) for correct trials, standard errors of means, and mean percentages of errors in the experimental conditions are presented in Table 1. Trials with incorrect naming or manual classification, stuttering, mouth clicks, or vocal hesitations, and trials with omissions, voice key failures, or malfunctioning were discarded from the RT analysis (a total of 6, or 3%). ANOVAs were performed with the within-subjects and within-items factors of task (naming, manual name classification) and relatedness (categorically related, unrelated), and the between-subjects and within-items factor order of tasks (naming or name classification task first). Where necessary, the reported *p* values were corrected for the degrees of freedom using the Huyhn–Feldt procedure. All ANOVAs were calculated with participants and items as random factors (F_1 and F_2, respectively).

ANOVAs yielded a main effect of task [$F_1(1,20) = 177.4$, $MS_e = 5,805$, $p < .001$; $F_2(1,119) = 1,230.32$, $MS_e = 8,766$, $p < .001$], with shorter latencies in the naming than in the name classification task, and a main effect of relatedness [$F_1(1,20) = 15.2$, $MS_e = 534$, $p < .001$; $F_2(1,119) = 14.49$, $MS_e = 6,570$, $p < .001$], reflecting classic semantic interference effects with slower RTs in the related than in the unrelated condition. However, there was no interaction of task and relatedness (*F*s < 0.5), confirming the presence of interference in both tasks. The effect of task order was significant [$F_1(1,20) = 4.4$, $MS_e = 28,850$, $p < .05$; $F_2(1,119) = 182.02$, $MS_e = 6,856$, $p < .001$], reflecting faster mean RTs in the group starting with the naming task ($M = 944$) relative to the group starting with the classification task ($M = 1,020$). Task order interacted with task [$F_1(1,20) = 23.3$, $p < .001$; $F_2(1,119) = 271.48$, $MS_e = 5,272$, $p < .001$], with a smaller difference between tasks in the group starting with the naming relative to the group starting with the classification task ($M_{diffs} = 138$ and 295, respectively), and a trend for an interaction of task order and relatedness [$F_1(1,20) = 2.9$, $p = .10$; $F_2(1,119) = 4.6$, $MS_e = 5,095$, $p < .05$]. Importantly, however, there was no three-way interaction of task order, task, and relatedness (all *F*s < 1).

Table 1
Mean Reaction Times (RTs, in Milliseconds) and Percentage Error Rates, With Standard Errors of the Means (*SEM*s), for the Naming and Name Classification Tasks

	Task							
	Naming				Name Classification			
	RT		% Errors		RT		% Errors	
Distractor	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*
Related	886	15.5	5.9	0.9	1,099	29.6	6.6	0.6
Unrelated	863	14.6	4.8	0.8	1,082	27.9	6.1	0.7
Difference	23		1.1		17		0.5	

Paired *t* tests for the two tasks revealed reliable relatedness effects in the naming task [$t_1(21) = 3.93$, $p < .001$; $t_2(119) = 3.65$, $p < .001$] and in the name classification task [$t_1(21) = 2.12$, $p < .05$; $t_2(119) = 2.04$, $p < .05$]. An additional analysis including the within-participants and between-items factor response congruency (picture and distractor name ending with a vowel/consonant or differently), reported in the supplement, yielded a main effect of this factor but no interaction with relatedness, and no three-way interaction of task, relatedness, and congruency (*F*s < 2). ANOVAs on mean error rates (cf. Table 1) revealed no main effects or interactions (all *F*s < 2.35; *p*s $> .13$).

DISCUSSION

In the present study, we investigated the competitive nature of lexical selection during speech planning with the PWI paradigm, a widely used task for investigating core mechanisms of lexicalization. We contrasted semantic distractor effects in a naming and a manual name classification task. In the naming task, target names were overtly articulated, resulting in classic semantic interference effects that can be localized at the level of lexical selection or, alternatively, in the articulatory output buffer. Crucially, however, similar interference effects were observed in the name classification task. This task includes speech planning processes up to the level of morphophonological encoding but does not require articulation. The observation of interference effects in both response modalities is in contrast to the predictions derived from the response exclusion account. Interference effects should only be observed in tasks that require overt articulation. If the output buffer is bypassed in the classification task, facilitation, rather than interference, should be seen. However, we have found no sign of a modality-specific dissociation of semantic distractor effects. The observed interference effects were comparable in the naming task with overt articulation, and in the name classification task without overt articulation.

Can the semantic interference effects in the manual task be accounted for by assuming that articulatory processes are involved despite the fact that only manual classifications are required? This is, in our view, very unlikely. The name classification task involves silent naming or inner speech, and silent naming tasks have often been shown not to include articulatory processes. For instance, Huang, Carr, and Cao (2001; see also Bookheimer, Zeffiro, Blaxton, Gaillard, & Theodore, 1995) have found no evidence for the activation of areas associated with vocalizations in an fMRI study. Likewise, participants in the present study showed no tendency to articulate the names in the manual task. Because there was no three-way interaction of task order, task, and relatedness, this seems to hold even when the pictures had already been named in the first part of the experiment. Thus, silent or covered naming does not seem to include articulatory processes.

Independent support for these conclusions stems from a study by Oppenheim and Dell (2008), demonstrating that inner speech is specified at a lexical, but not at a featural or articulatory level. In a tongue twister recitation task, lexical bias effects (the stronger tendency for phonological errors to result in existing words as opposed to nonwords) were present in overt and reported inner speech errors, whereas, importantly, phonemic similarity effects (the greater likelihood of producing phonemes that are articulated more similarly than other phonemes) were observed only in overt speech. This suggests that silent speech is sensitive to lexical but not to phonetic properties. Furthermore, Wheeldon and Levelt (1995) have demonstrated that the monitoring of internal speech for target segments—assessed with manual classifications very similar to the classification task used here—is based on phonological encoding processes, not on phonetic or articulatory codes. Most important for the present purpose, the authors have shown that a concurrent articulation task (counting from one onward during the entire period from stimulus presentation to the manual classification response; Experiment 1B) had a very limited effect on performance. If the classification task were based on phonetic processes, the additional articulation should have greatly affected performance in this task. Together, the findings of Oppenheim and Dell (2008) and Wheeldon and Levelt (1995) strongly suggest that the manual task employed in the present study does not involve articulatory processes.

Because the representations underlying the classification task are localized at planning levels before the start of articulatory processes, the observed semantic interference effects cannot be reconciled with a single-channel articulatory output buffer, as proposed by the response exclusion hypothesis. This leaves us with one theoretical option to preserve a noncompetitive position: One might argue that interference in the manual task reflects a bottleneck outside the articulators. For instance, analogously to the articulatory buffer in the naming task, there might be an orthographic output buffer in the manual task, to which printed words have direct access and need to be removed before the classification task can be executed. Alternatively, the single channel might be localized at earlier phonological stages of prearticulatory monitoring, or may even reflect limited working memory capacities. However, to our knowledge, no theoretical position makes such claims, and we are not aware of any empirical evidence for the existence of an orthographic or phonological output buffer. In fact, these assumptions are in contrast to robust facilitation effects induced by words that are orthographically/phonologically similar—but not identical—to the target name (e.g., Starreveld & La Heij, 1995). Thus, the most parsimonious account for semantic interference in tasks with and without articulation, directly derived from lexical competition models, is stronger interference from related relative to unrelated words at the level of lexical selection.

Even if one would assume that interference effects take place in the output buffer, the question remains whether semantically related distractors are relevant responses in the classification task. Mahon et al. (2007) defined the factor of response relevance somewhat flexibly, as follows: "There are, in principle, an indefinite number of response-relevant criteria, because such criteria are, in part, a product of task constraints decided by the experimenter" (p. 512). Thus, depending on the task at hand, different types of distractors can be response relevant or irrelevant. Now, given that the responses in the classification task are determined by the end segments of the picture names, one could argue that only words that share the critical feature of ending with a vowel or consonant (i.e., response-congruent words) should be relevant. In this case, incongruent distractors that do not share this feature should be removed more quickly from the output buffer. However, the additional analysis, including the factor response congruency, presented in the supplement, did not yield a differential effect of name congruency on the classification task.

To summarize, our data demonstrate that semantic interference effects are related to processes that do not require the generation of articulatory output. These findings thus speak against a localization in the articulators. Moreover, the reported exceptions from categorical–semantic interference effects in the PWI paradigm can be explained without assuming an articulatory bottleneck. For instance, Kuipers and colleagues (Kuipers & La Heij, 2008; Kuipers et al., 2006) have demonstrated that the combination of spreading activation, facilitation due to message congruency between target and distractor, and lexical competition can account for polarity reversals of semantic context effects. Similarly, Abdel Rahman and Melinger (2009a, 2009b; but see also Mahon & Caramazza, 2009) have suggested that trade-offs between conceptually induced facilitation and competition due to lexical cohort activation can account for a wide spectrum of inhibitory and facilitatory context effects in picture naming.

In conclusion, we demonstrate semantic interference effects of similar magnitude in tasks with and without articulation, supporting lexical competition accounts. A bottleneck in the articulatory output buffer does not seem to be a critical determinant for semantic context effects in the PWI paradigm.

AUTHOR NOTE

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SUPPLEMENTAL MATERIALS

Supplemental analyses and lists of the stimuli in the article may be downloaded from http://pbr.psychonomic-journals.org/content/supplemental.

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