Electrophysiological Chronometry of Semantic Context Effects in Language Production

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Abstract

■ In this study, we investigated semantic context effects in language production with event-related brain potentials, extracted from the ongoing EEG recorded during overt speech production. We combined the picture–word interference paradigm and the semantic blocking paradigm to investigate the temporal dynamics and functional loci of semantic facilitation and interference effects. Objects were named in the context of semantically homogeneous blocks consisting of related objects and heterogeneous blocks consisting of unrelated objects. In each blocking condition, semantically related and unrelated distractor words were presented. Results show that classic patterns of semantically induced facilitation and interference effects in RTs can be directly related to ERP modulations located at temporal and frontal sites, starting at about 200 msec. Results also suggest that the processes associated with semantic facilitation and interference effects (i.e., conceptual and lexical processing) are highly interactive and coincide in time. Implications for the use of event-related brain potentials in speech production research and implications for current models of speech production are discussed. ■

INTRODUCTION

Lexical access, the selection of words from the mental lexicon that correspond to the to-be-expressed preverbal message, is one of the central components of the speech production system (e.g., Levelt, 1999; Caramazza, 1997; Starreveld & La Heij, 1996; Dell, 1986). It is often investigated with behavioral measures of semantic context effects. Specifically, in the picture–word interference paradigm (PWI) a picture is presented for a naming response together with a to-be-ignored distractor word. Semantically related words can hamper or facilitate naming compared with unrelated words (e.g., Hantsch, Jescheniak, & Schriefers, 2005; Costa, Mahon, Savova, & Caramazza, 2003; La Heij, Heikoop, Akerboom, & Bloem, 2003; Alario, Segui, & Ferrand, 2000; Levelt, Roelofs, & Meyer, 1999; Glaser & Glaser, 1989). In the semantic blocking paradigm, similar context effects are induced by presenting objects in homogeneous blocks of trials, consisting of semantic category or associative context members. Again, compared with heterogeneous blocks with semantically unrelated objects, this manipulation has been shown to hamper and/or facilitate the naming response (Abdel Rahman & Melinger, 2007; Belke, Meyer, & Damian, 2005; Damian & Als, 2005).

Although semantic context effects have provided important implications for models of speech production, their functional and temporal localization is a matter of continuing debate. Semantic interference effects—reliably reported for categorical relations (e.g., spring roll and hamburger)—have long been taken as evidence for a competitive mechanism at the level of lexical selection (e.g., Schriefers, Meyer, & Levelt, 1990). Upon preparing a naming response (e.g., naming the picture of a hamburger), semantic activation spreads through a network of semantically related concepts (french fries, sandwich etc.; cf. Collins & Loftus, 1975), which in turn activate their lexical entries (lemmas). These lexical correlates of the related concepts compete with the target lemma for selection (Levelt et al., 1999). Providing a semantic context either by simultaneously presenting a categorically related distractor word (e.g., the word *steak*) or by embedding the target picture within a block of pictures that also depict types of food (i.e., homogeneous blocks) causes additional activation of the related concepts and their corresponding lexical entries. This enhances the competition and delays lemma selection, resulting in slower naming times. In this model, conceptual and lexical activation spread is bidirectional and temporally coincident.

The observation that not all semantic relations induce interference effects has cast doubt on the assumption that the slowdown of naming latencies has a lexical locus. For example, associative or part–whole relations seem to induce facilitation rather than interference (e.g., Costa, Alario, & Caramazza, 2005; Alario et al., 2000; but see Abdel Rahman & Melinger, 2007; for a recent review of semantic facilitation effects, see Mahon, Costa, Peterson, Vargas, & Caramazza, 2007). On the basis of the pattern of semantic interference and facilitation effects, a recent proposal has suggested that lexical selection is not

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a competitive process (Mahon et al., 2007; Costa et al., 2005). Instead, the source of semantic interference is assumed to be postlexical, arising in the articulatory output buffer. When a distractor word is categorically related to the target, it blocks the single-channel output buffer, thus delaying articulation. Semantic facilitation is assumed to take place as priming at the conceptual level (Costa et al., 2005) or at the lexical level (Mahon et al., 2007). Thus, in this model, contextually induced facilitation and interference are located at distinct and clearly separable processing stages.

With the present article, we aim to contribute to the debate on the time course and functional loci of semantic interference and facilitation effects by exploiting the high temporal resolution of event-related brain potentials extracted from the EEG recorded during overt speech production.

Overt Articulation and Event-related Brain Potentials

In contrast to the wide use of ERPs in comprehension research (for a review, see Osterhout & Holcomb, 1995), there are to date only a few studies on language production using ERPs. The main reason not to make use of electrophysiological measures has been an assumed contamination of the signal by artifacts. Overt speaking is associated with facial muscle activity, lip and eye movements, glossokinetic potentials, and head movements, all of which can obscure the EEG signal severely (e.g., Wohlert, 1993; Brooker & Donald, 1980; Grözinger, Kornhuber, & Kriebel, 1975). To avoid these problems, some studies have used tasks allowing for EEG acquisition in the absence of overt speech, such as delayed and covert naming or manual classification tasks (Abdel Rahman & Sommer, 2003; Abdel Rahman, van Turennout, & Levelt, 2003; Schmitt, Schiltz, Zaake, Kutas, & Münte, 2001; Schmitt, Münte, & Kutas, 2000; van Turennout, Hagoort, & Brown, 1997, 1998). Although these alternatives successfully avoid speech-related artifacts, they have several disadvantages. When naming is delayed or covert, behavioral measures are not available. In silent-naming tasks, compliance with the instructions cannot be controlled for and, more importantly, a direct comparison of RT and error data with electrophysiological variables is not possible. Alternatively, when naming is substituted by button-press responses, it is hard to estimate which of the observed effects are genuinely language related. Thus, studying overt speech would clearly be preferable to the above-described methods.

Some evidence has been provided about RT effects reflected in ERPs during overt speech, for instance within Stroop paradigms (e.g., Liotti, Woldorff, Perez, & Mayberg, 2000; Duncan-Johnson & Kopell, 1981). However, these studies have some methodological limitations. For example, the early study by Duncan-Johnson and Kopell (1981) used only three midline electrodes. Other studies were limited by small sample sizes and by ERP analyses confined only to late time windows (e.g., 400–800 msec poststimulus onset; Liotti et al., 2000). Recently, several new attempts have been made to combine EEG recordings with overt speech production (e.g., Aristei, Abdel Rahman, Job, & Kiefer, under revision; Strijkers, Costa, & Thierry, 2010; Verhoef, Roelofs, & Chwilla, 2006, 2009; Abdel Rahman & Sommer, 2008; Ganushchak & Schiller, 2008; Hirschfeld, Jansma, Bölte, & Zwitserlood, 2008; Koester & Schiller, 2008; Verhoef, 2008; Christoffels, Firk, & Schiller, 2007; Schmitt, Bles, Schiller, & Münte, 2002; Greenham, Stelmack, & Campbell, 2000). One of the aims of the present study was to further assess the feasibility and the benefits of investigating the dynamics of overt speech production with ERPs. In particular, we explore semantic context effects with ERPs while participants overtly name pictures. Before turning to the specific objectives, we will review the available EEG and fMRI evidence on semantic context effects in speaking.

Semantic Context Effects in Speech Production: Neural and Electrophysiological Evidence

In a comprehensive meta-analysis on the neural and temporal correlates of speech production, Indefrey and Levelt (2000, 2004) evaluated a large number of neuroimaging studies. Most of these studies focused on the identification of cerebral regions involved in speech production, mainly reporting fMRI and PET data. The analysis identified the midsection of the left middle temporal gyrus as the one region that was reliably associated with conceptual preparation and lexical selection. However, a distinction between the two processes was not possible. Recent fMRI studies on semantic interference effects with the semantic blocking paradigm (Schnur, Schwartz, Brecher, & Hodgson, 2006; Schnur, Hirshorn, & Thompson-Schill, 2005; Schnur, Lee, Coslett, Schwartz, & Thompson-Schill, 2005), the PWI paradigm (de Zubicaray, Wilson, McMahon, & Muthiah, 2001), and the competitor priming paradigm (de Zubicaray, McMahon, Eastburn, & Pringle, 2006) have also shown that interference is associated with higher activation in the left temporal cortex. Additionally, however, all of the latter studies reported higher activation patterns in the left inferior frontal gyrus (see also Moss et al., 2005). This frontal interference effect has been taken to reflect selection among competing semantic alternatives (stored in temporal areas), whereas the temporal effects have been taken to reflect the activation of semantically related competitors (e.g., Schnur et al., 2006; Schnur, Hirshorn, et al., 2005; Schnur, Lee, et al., 2005; but see de Zubicaray et al., 2001, 2006).

Because of their poor temporal resolution, the above brain imaging techniques are not informative as to the time course of semantic context effects. As discussed earlier, studies providing direct evidence on context effects as they evolve over time are scant. An early study that directly assessed the time course and the neural correlates of semantic context effects during overt picture naming used MEG (Maess, Friederici, Damian, Meyer, & Levelt, 2002). In a semantic blocking study, pictures were named in homogeneous blocks of categorically related objects or in heterogeneous blocks of unrelated objects. Categorical blocking induced a classic semantic interference effect in RTs. Furthermore, the authors demonstrated that activation in the midsection of the left middle temporal gyrus varied systematically with semantic blocking between 150 and 225 msec after stimulus onset. In line with Indefrey and Levelt (2000, 2004), the authors concluded that the left temporal cortex reflects semantic interference effects at the level of lexical selection. In contrast to several fMRI studies on lexical interference (see previous section), Maess et al. (2002) did not report differential frontal activity. More recently, ERPs were recorded during overt naming in a study using a semantic blocking paradigm (Ganushchak & Schiller, 2008). However, in this study, only response-locked ERPs associated with self-monitoring and error-related processing were reported.

Another attempt to study context effects in speech production through the combination of ERPs and overt naming is a recent study by Hirschfeld et al. (2008). The authors conducted a PWI experiment that compared nonlinguistic and unrelated distractor words to two types of semantic distractors, words that reflect a surface feature of the target word (e.g., TARGET—dog, DISTRACTOR—fur) and words from the same semantic category (e.g., TARGET—dog, DISTRACTOR—cat). Unfortunately, this study failed to observe reliable ERP correlates of semantic interference. However, the study did reveal that surface features produced a more negative going deflection than unrelated words in an early time window between 120 and 220 msec after stimulus onset. The early effect for surface features, which was widely distributed, was interpreted as facilitating early stages of visual object processing; hence, it does not advance the discussion of the involvement of temporal and frontal regions in conceptual preparation or lexical selection. However, the study does highlight the difficulty in revealing reliable differences in ERP components that underlie even robust behavioral effects such as semantic interference from categorically related distractor words.

To summarize, the discussed studies provide rather consistent evidence for a significant involvement of left frontal and temporal regions in conceptual and lexical effects during language production. However, much less is known about the temporal dynamics of these effects, about their functional locus within the speech production system, or about the relation between context effects inducing interference versus facilitation.

Exploring Semantic Context Effects with ERPs

With the present study, we aim to shed light on the less explored issues of the temporal microstructure of semantic context effects by investigating overt picture naming with event-related brain potentials. To this purpose, we combined the PWI and the semantic blocking paradigms. Both have been frequently used in language production research, and both yield well-established semantic interference and facilitation effects. The high temporal resolution provided by ERPs should reveal fine-grained information about the time course of different language production components and their interactions that isolated RT measures cannot offer. The specific objectives of this study are as follows.

First, we assessed the feasibility of combining overt speaking with the ERP technique. Second, we aimed to identify the electrophysiological correlates of semantic context effects during speaking, and assess whether the well-attested patterns of interference and facilitation can be related to specific ERP modulations. The temporal dynamics of these context-induced ERP modulations should allow a comparatively precise localization of the effects within the speech production system and should thus contribute to a distinction between opposing theoretical accounts on the origins of interference and facilitation effects (see previous section).

The third aim was to investigate the relationship between semantic context effects of different polarities: Are facilitation and interference effects located at the same or interacting processing stages, as suggested by lexical competition models (e.g., Bloem & La Heij, 2003; Damian, Vigliocco, & Levelt, 2001; Levelt et al., 1999), or are they located at different and noninteracting processing stages, as suggested by a recent proposal (e.g., conceptual/lexical facilitation due to semantic priming and postlexical interference due to a bottleneck located in the output buffer; Mahon et al., 2007; Finkbeiner & Caramazza, 2006)? A direct comparison of the time course and the distribution of the ERP modulations associated with interference and facilitation should reveal whether context effects of different polarities can be dissociated temporally and functionally or whether they are subserved by interacting processing stages. In addition, we can compare the time course of the ERP modulations associated with the interference effects induced by the PWI and semantic blocking paradigms to determine whether they share the same underlying mechanism.

Finally, a more specific aim was to investigate context effects for different types of semantic relations. Specifically, as discussed above, several studies have shown that whereas categorical relations induce classic interference effects, associative relations induce facilitation in the PWI paradigm (e.g., Abdel Rahman & Melinger, 2007; Bölte, Jorschick, & Zwitserlood, 2003; Alario et al., 2000). Abdel Rahman and Melinger (2007, 2009a, 2009b; but see Mahon & Caramazza, 2009) have suggested that interference is only observed when a lexical cohort of sufficient size is active, with each member of the cohort contributing to the competition. Otherwise, conceptual priming will outweigh lexical competition. Such a cohort is likely active for categorical relations because of a converging spread of activation to a number of common category members (e.g., food). However, associates typically stand in a one-to-one relation (e.g., an American and a baseball cap). Thus, they do not costimulate a cohort of lexical competitors and therefore induce facilitation in a PWI situation. In line with this assumption, semantic blocking of associates does induce interference. In this paradigm, multiple associates of a common semantic context are mutually interrelated, creating the one-to-many relationship that gives rise to a lexical cohort (e.g., context America: The White House, a hamburger, the prairie), all members of which compete for selection. Thus, the facilitation effect observed with the PWI paradigm can be turned into an interference effect in the blocking paradigm.

In the present study, we combine these two paradigms to investigate interactions between the effects produced by the two types of context manipulations (block and distractor word). In accordance with the earlier hypothesis, a stronger interaction between the two effects is expected for associates compared with category members. Specifically, the polarity of the effects elicited by associatively related distractors should depend on semantic blocking: Associatively induced facilitation from related distractors is expected in the heterogeneous blocks, but this facilitation should be reduced or even reversed in associatively homogeneous blocks. This is because the homogeneous blocks activate a lexical cohort, which is crucial for the emergence of observable semantic interference effects. Associatively related distractors on their own do not activate a cohort, but in the context of an associatively related block of pictures, the distractor word can benefit from the converging activation, hence producing more interference than would normally be produced by a single distractor in isolation. In contrast, categorically related distractor effects should be relatively stable across semantic block types. This is because categorical relations naturally produce semantic cohort activation, so the blocking manipulation should not qualitatively change the effect of distractor words.

METHODS

Participants

Thirty right-handed native German speakers (age range = 18–47 years, mean = 27 years) were paid for their participation in the experiment or received partial fulfillment of a curriculum requirement. All reported normal or corrected-to-normal vision. Two participants were replaced because of high error rates. All participants gave informed consent, in accordance with the Declaration of Helsinki.

Materials

Twenty-five color photographs of objects were selected. The objects were orthogonally distributed between five semantic categories (nationalities, headpieces, landscapes, monuments, and food) and five semantic contexts (China, France, Russia, Saudi Arabia, and United States). Target pictures were presented in categorically homogeneous blocks (all objects were category members, e.g., headpieces), associatively homogeneous blocks (all objects were members of a common semantic context, e.g., China), or heterogeneous blocks (objects were categorically and associatively unrelated; Figure 1 shows all pictures and the homogeneous blocking conditions). Each picture was presented in combination with three different auditory distractor words, which were categorically related, associatively related, or unrelated to the depicted object. Auditory distractors were taken from the set of target picture names. The size of the photographs was 3.5 × 3.5 cm at an approximate viewing distance of 90 cm from the monitor.

Procedure and Apparatus

Stimulus presentation and response recording was controlled by the Presentation software (Neurobehavioral Systems Inc., Albany, CA). Vocal responses were recorded through a microphone, and naming latencies were measured with a voice key. Naming accuracy and voice key functioning were monitored on-line by the experimenter. Each trial began with the presentation of a fixation cross in the middle of the screen. After 500 msec, the distractor word was presented auditorily, followed by the target picture after 150 msec (SOA = −150 msec). The picture remained on the screen until vocal response, with a maximum duration of 2500 msec. Before the experiment, participants were familiarized with the visual stimuli and their names as follows: First, all photographs were presented in random order on the screen, and participants were asked to name each picture. If necessary, they were corrected or the picture name was provided by the experimenter. Then participants were given a printed color sheet with all pictures and their names printed below.

The experimental session unfolded as a series of miniblocks, each consisting of five pictures presented repeatedly (for a description of the session as presented to one participant, see Table 1). Within each miniblock, each picture occurred four times in each distractor condition, namely, four times with a categorically related distractor word, four times with an associatively related distractor word, and four times with an unrelated distractor word. Hence, each of the five pictures was repeated 12 times for a total of 60 trials per miniblock.

Fifteen miniblocks were presented in total. Five consisted of pictures drawn from a common semantic category (i.e., categorically homogeneous blocking condition), five consisted of pictures drawn from a common semantic context (i.e., associatively homogeneous blocking condition), and five consisted of unrelated pictures (i.e., heterogeneous blocking condition). Pictures were distributed between the miniblocks, with each picture occurring in one miniblock from each blocking condition. Hence, each

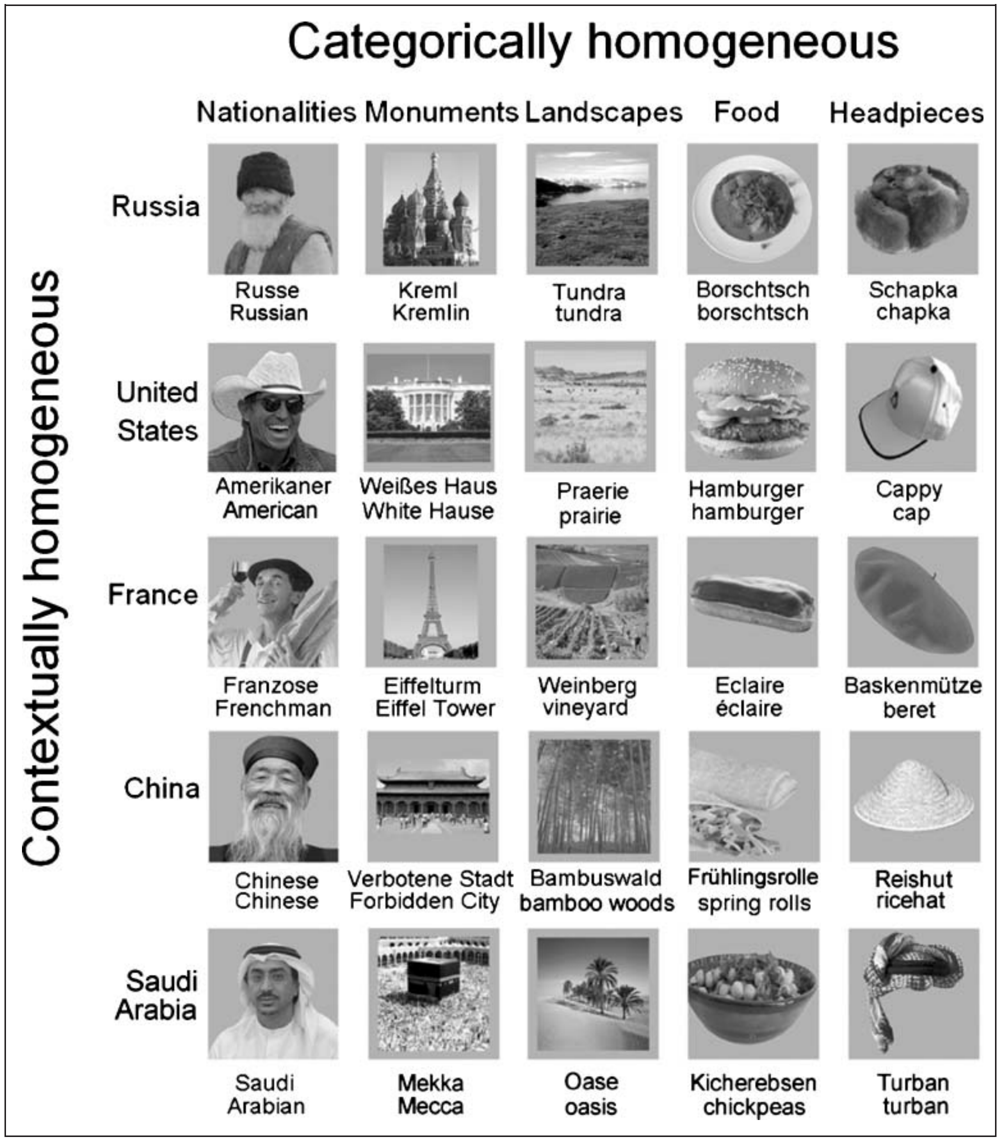

Figure 1. Illustration of the pictures presented in the experiment. The pictures were presented in associatively and categorically homogeneous blocks and in heterogeneous blocks consisting of associatively and categorically unrelated objects.

picture was repeated 12 times in each of its three miniblocks and 36 times across the entire experiment, resulting in a total of 900 trials within the whole experimental session, which lasted about 90 minutes.

All the miniblocks of a particular blocking condition (i.e., categorically homogeneous, associatively homogeneous, or heterogeneous) were presented consecutively. In other words, the factor semantic blocking condition was itself blocked within the experiment. In contrast, the factor distractor relatedness was randomized; all three distractor conditions were presented within each miniblock, and their order of presentation was fully randomized for each participant, as was the order of picture presentation within a miniblock. The order of the miniblocks within a semantic blocking condition and the order of semantic blocking conditions themselves were counterbalanced across participants (see Table 1). The miniblocks were separated by breaks during which participants could rest and execute eye and small body movements. Participants were instructed to name the depicted objects as quickly and accurately as possible. They were also informed that they would hear a word shortly before the appearance of the object and were asked to ignore it. Participants were not informed of the semantic blocking or the relatedness between target utterance and distractor word.

EEG Recording and Analysis

The continuous EEG was recorded with sintered Ag/AgCl electrodes from 56 sites according to the extended 10–20 system, referenced to the left mastoid, and at a sampling rate of 500 Hz (band-pass filter = 0.032–70 Hz). The horizontal and vertical EOG was measured with external electrodes attached to the left and right canthi of both eyes and beneath and above the left eye. Electrode

Table 1. Condition Scheme as Presented to an Actual Participant

Semantic Blocking Conditions: Categorically Homogeneous, Associatively Homogeneous, Heterogeneous (Order Counterbalanced across Participants)								
Categorically Homogeneous: Five Miniblocks (Order Counterbalanced for Each Participant)			*Associatively Homogeneous: Five Miniblocks (Order Counterbalanced for Each Participant)*			*Heterogeneous: Five Miniblocks (Order Counterbalanced for Each Participant)*		
Miniblock 1		Miniblocks 2–5	Miniblock 1		Miniblocks 2–5	Miniblock 1		Miniblocks 2–5
For example, headpieces		For example, monuments, food, landscapes, nationalities	For example, United States		For example, China, France, Russia, Saudi Arabia	For example, Mix 1		For example, Mix 2, Mix 3, Mix 4, Mix 5
Presentation 1 of each picture–distractor pair (categorically related, associatively related, unrelated)	Presentations 2 to 4	Same procedure	Presentation 1 of each picture–distractor pair (categorically related, associatively related, unrelated)	Presentations 2 to 4	Same procedure	Presentation 1 of each picture–distractor pair (categorically related, associatively related, unrelated)	Presentations 2 to 4	Same procedure
(order randomized)			(order randomized)			(order randomized)		
For example:			For example:			For example:		
cap /turban/; /White House/; /éclair/			**American** /Frenchman/; /cap/; /oasis/			**American** /Frenchman/; /cap/; /oasis/		
ricehat /cap/; /Forbidden City/; /tundra/			**cap** /turban/; /White House/; /éclair/			**ricehat** /cap/; /Forbidden City/; /tundra/		
beret /chapka/; /Eiffel Tower/; /spring roll/			**White House** /Forbidden City/; /hamburger/; /Arabian/			**vineyard** /tundra/; /beret/; /Forbidden City/		
chapka /beret/; /tundra/; /hamburger/			**hamburger** /borschtsch/; /prairie/; /Frenchman/			**Kremlin** /White House/; /Russian/; /bamboo woods/		
Turban /ricehat/; /chickpeas/; /american/			**prairie** /bamboo woods/; /American/; /Mecca/			**chickpeas** /hamburger/; /Arabian/; /vineyard/		

Within each semantic blocking condition (categorically/associatively homogeneous, heterogeneous), the left column refers to the first miniblock presented (e.g., headpieces). The picture–word pairs that constituted the miniblocks are specified at the bottom of the same column. Each miniblock was repeated four times. Thus, as can be seen at the bottom of the columns describing the miniblocks, "Presentation 1" always refers to the first three presentations of each picture with all three distractor conditions.

impedance was kept below 5 kΩ for all scalp electrodes and below 10 kΩ for peripheral sites.

Off-line EEG data were rereferenced using the average reference transformation and low-pass filtered (high cutoff = 30 Hz, 24 dB/oct). Eye movement artifacts were removed with a spatio-temporal dipole modeling procedure using the BESA software (Berg & Scherg, 1994). The method built-in in BESA is based on the spatial components approach described in Berg and Scherg (1994). Artifacts are defined on the basis of their spatial topographies throughout the whole EEG track. Once the topography for each type of artifact (blinks, horizontal, and vertical eye movements) has been determined, the artifact signal is reconstructed at each electrode and subtracted from the continuous EEG signal.

Remaining artifacts were eliminated with a semiautomatic artifact rejection procedure. Segments with potentials exceeding 50.00 μV voltage step per sampling point and a threshold of 200.00 μV were excluded from further analyses. Error- and artifact-free EEG data were segmented into epochs of 2250 msec, starting 100 msec before the onset of the distractor word, providing a 100-msec baseline interval before distractor onset. Trials were averaged separately for each blocking and distractor condition. Because the fastest RTs were over 500 msec, there was no need to apply an exclusion threshold (e.g., 300-msec naming latency), which is often used to exclude trials with very quick speech onsets, which would contaminate the ERPs. Moreover, because the morphology of speech artifacts largely depends on the phonetic properties of the words, we further minimized the possibility that differences between conditions could be caused by articulation artifacts because the same verbal responses were given across conditions. Thus, even if ERPs were still contaminated by speech artifacts, they would affect the experimental conditions of interest equally.

RESULTS

Behavioral Results

Mean RTs for correct trials, mean standard errors, and mean percentages of errors in the experimental conditions are presented in Table 2. The error rates were low (2.6% on average) and thus are not analyzed further. Trials with incorrect naming, stuttering, mouth clicks, or vocal hesitations and trials with voice key failures or malfunctioning were discarded from the RT analysis.

ANOVA on RTs were performed with the within-participants factors semantic blocking (categorically homogeneous, associatively homogeneous, and heterogeneous), distractor relatedness (associatively related, categorically related, and unrelated), and repetition (four levels). Because of the combined manipulation of semantic blocking and distractor relatedness, the "first presentation" in the present experiment refers to the first presentation of a given object in a specific blocking and distractor condition (cf. Table 1). Therefore, repetition one includes three presentations of one object, once in each of the three distractor conditions. The complexity of the design offers

Table 2. Mean Naming Latencies (RTs, in milliseconds), Standard Errors of Means, and Mean Percentage of Errors (Err, in percent) for the Semantic Blocking and Distractor Conditions and Repetitions

	First Repetitions			*Second Repetitions*			*Third Repetitions*			*Fourth Repetitions*		
Distractor Relatedness	*RT (msec)*	*SE*	*Err %*	*RT (msec)*	*SE*	*Err %*	*RT (msec)*	*SE*	*Err %*	*RT (msec)*	*SE*	*Err %*
Associatively Homogeneous Context												
Associative	762	16.00	2.4	746	17.7	1.7	750	19.4	1.2	733	18.2	1.9
Categorical	786	16.49	3.9	750	18.0	2.1	743	18.9	2.0	745	17.6	1.7
Unrelated	768	18.31	2.8	745	17.1	2.3	743	17.8	2.7	752	20.4	1.9
Categorically Homogeneous Context												
Associative	757	17.6	4.7	756	16.7	4.0	755	20.9	2.7	759	17.5	2.7
Categorical	789	20.4	3.6	775	18.7	2.8	767	17.2	2.5	770	17.1	2.4
Unrelated	779	19.4	2.9	755	17.2	2.3	760	17.1	3.5	773	19.0	2.5
Heterogeneous Context												
Associative	762	19.5	2.3	719	16.8	2.5	733	19.4	1.5	727	19.3	1.9
Categorical	794	18.8	3.7	762	21.8	2.7	739	19.9	2.4	743	20.3	1.6
Unrelated	777	15.8	4.0	738	17.4	3.2	741	20.1	4.4	752	19.4	3.1

One repetition includes three presentations of each picture with all three distractor conditions.

extensive possibilities for analysis. However, in the interest of clarity, we restricted our analyses to those most economically designed to evaluate our aims and predictions.

All ANOVAs were calculated with participants and items as random factors (F_1 and F_2, respectively). Where necessary, the reported p values are corrected for the degrees of freedom using the Huyhn–Feldt procedure, and the correction factor (ε) is indicated.

The omnibus ANOVA yielded the predicted main effect of Semantic Blocking in the items analysis, $F_2(2, 48) = 8.455$, $MSE = 3054$, $p < .001$, and a trend in the participants analysis, $F_1(2, 58) = 2.369$, $MSE = 13114$, $p = .103$. A main effect of Distractor Relatedness was also obtained, $F_1(2, 58) = 15.850$, $MSE = 2037$, $p < .001$, $\varepsilon = 0.80$ and $F_2(2, 48) = 5.903$, $MSE = 3632$, $p < .005$, as well as a Repetition main effect, $F_1(3, 87) = 6.415$, $MSE = 15707$, $p < .01$, $\varepsilon = 0.44$ and $F_2(3, 72) = 35.079$, $MSE = 1086$, $p < .001$. Thus, it appears that when the two semantic context manipulations are combined together, they replicate the patterns observed by each context individually. Furthermore, there was an interaction of Distractor Relatedness and Repetition, $F_1(6, 174) = 3.857$, $MSE = 1187$, $p < .001$ and $F_2(6, 144) = 3.987$, $MSE = 920$, $p < .001$. The interaction of Semantic Blocking and Distractor Relatedness reached significance in the items analysis, $F_2(6, 144) = 35.079$, $MSE = 963$, $p < .001$, $\varepsilon = 0.81$, but not in the participants analysis, $F_1(4, 116) = 1.32$, $MSE = 2091$, $p = .27$, $\varepsilon = 0.78$. This interaction will be further analyzed (see next section) taking into account the predictions from our hypotheses about associative and categorical relations.

As has been observed before (Abdel Rahman & Melinger, 2007; Belke et al., 2005), semantic blocking effects differ between first repetitions and all subsequent repetitions within that block. Although at the start of a presentation block there were only minimal differences between the heterogeneous and the two homogeneous conditions, the blocking effects stabilized after the first repetitions, with slower naming times in both types of homogeneous blocks compared with the heterogeneous blocks. This is confirmed by an ANOVA excluding the first repetitions.[1] In this analysis, the main effect of Semantic Blocking was highly significant, $F_1(2, 58) = 5.26$, $MSE = 8106$, $p < .008$ and $F_2(2, 48) = 11.607$, $MSE = 3075$, $p < .001$, whereas both the main effects of Repetition and the interaction vanished (all Fs < 1).

The hypothesis that the effects of associatively related distractors should be modulated by blocking more strongly than those of categorically related distractors was tested with separate analyses for the two types of relations (see also Figure 3). For associative relations, the ANOVA with the factors Semantic Blocking (associatively homogeneous or heterogeneous), Distractor Type (associatively related or unrelated), and Repetition (four levels) revealed a main effect of distractor type, $F_1(1, 29) = 12.037$, $MSE = 1077$, $p < .002$, which was marginally significant in the analysis by items, $F_2(1, 24) = 3.661$, $MSE = 2772$, $p = .068$, with naming times in the associatively related distractor condition faster than that in the unrelated distractor condition. The effect of Blocking failed to reach significance, when the first repetitions were included, whereas the Repetition main effect was significant, $F_1(3, 87) = 5.311$, $MSE = 8041$, $p < .05$, $\varepsilon = 0.54$ and $F_2(3, 72) = 18.921$, $MSE = 1362$, $p < .001$, $\varepsilon = 0.79$. The Blocking × Repetition interaction reached significance in the analysis by items only, $F_2(3, 72) = 5.41$, $MSE = 687$, $p < .05$ ($F_1 < 1$). Most importantly, we found a significant interaction of blocking and distractor, $F_1(1, 29) = 4.304$, $MSE = 1132$, $p < .05$ and $F_2(1, 24) = 5.412$, $MSE = 687$, $p < .03$. This interaction reflects the observation that associatively related distractors in the heterogeneous block sped naming times compared with unrelated distractors (related minus unrelated distractor conditions = -16.75 msec), $t_1(29) = -5.843$, $p < .001$, whereas the same distractors produced no reliable effects in the associatively homogeneous block ($M_{\text{diff}} = -4.25$ msec), $t_1(29) < 1$.

In an analogous analysis for categorical relations (semantic blocking: categorically homogeneous and heterogeneous; distractor relatedness: categorically related and unrelated; repetition: four levels), the Distractor Relatedness effect was marginally significant in the analysis by participants, $F_1(1, 29) = 4.089$, $MSE = 1848$, $p = .052$, but failed to reach significance in the analysis by items, $F_2(1, 24) = 1.197$, $MSE = 3830$, $p = .197$. Numerically, this effect of Distractor Relatedness reflects slower naming times produced in the categorically related distractor condition compared with the unrelated condition. The main effect of Semantic Blocking failed to reach significance. Repetition yielded a main effect as well as a significant interaction with Distractor Relatedness (Fs > 3, ps $< .05$, largest $p = .015$). The interaction between Blocking and Repetition was significant only in the analysis by items, $F_2(3, 72) = 4.588$, $MSE = 785$, $p < .01$ ($F_1 < 2$, $p > .1$). Here, and in clear contrast to the above-described effects for associative relations, there is no sign of an interaction of Blocking and Distractor Effects (related minus unrelated distractor $M_{\text{diff}} = 8.5$ and 7.5 msec for the homogeneous and heterogeneous blocks, respectively), Fs < 1. Thus, the behavioral results support the predictions of the lexical cohort activation account in so far as the distractor effects from associatively related distractor words were modulated by the semantic blocking manipulation whereas the distractor effects from the categorically related distractors were not.

Recently, Abdel Rahman and Melinger (2007) observed semantically induced facilitation rather than interference for initial-naming trials in the blocking paradigm. Specifically, RTs for the first repetitions of a picture were faster in homogeneous blocks than those in heterogeneous blocks. Post hoc comparisons revealed that this facilitation effect (faster RTs in homogeneous relative to heterogeneous blocks) only emerged when the experiment started with the heterogeneous condition—when the experiment started with the homogeneous blocking condition, interference (slower RTs in the homogeneous relative to the heterogeneous blocks) was already observed at the first repetitions of the pictures (in that study, as in the present study, the factor semantic blocking was blocked, such that all the heterogeneous miniblocks either preceded the homogeneous miniblocks or did not).

This effect was attributed by Abdel Rahman and Melinger (2007) to semantic context effects on the ease of object identification as follows: Identification should be particularly difficult when the objects have not been named often before (i.e., at the start of the experiment). Therefore, when participants begin the experiment, their RTs to the first repetitions of the pictures are particularly slow. However, participants starting with homogeneous blocks can use the semantic context (associative or categorical) to help identify the objects and thus the effort to overcome the initial difficulty in object identification should be reduced.

Therefore, when the naming times for the first repetitions in the experiment-initial heterogeneous blocks are compared with naming times for the first repetitions of the same pictures in subsequent homogeneous blocks, the difference results in a facilitation effect because the heterogeneous block cannot take advantage of any semantic context to cope with the initial object identification difficulty. In contrast, when the naming times for the first repetitions in the experiment-initial homogeneous blocks are compared with the naming times for the first repetitions of the same pictures in the subsequent heterogeneous block, there is no facilitation effect because the semantic context afforded by the homogeneous block could overcome or offset the initial object identification difficulties.

To assess whether the semantic facilitation for first presentations as reported in Abdel Rahman and Melinger (2007) could be replicated, we conducted an ANOVA confined to the first repetitions within each semantic blocking condition (in contrast to Abdel Rahman & Melinger, 2007, the first repetitions include three presentations of each object, one with each of the three distractor conditions). As associative and categorical contexts have revealed the same pattern of facilitation, we collapsed across the two homogeneous blocking conditions for this analysis. The ANOVA therefore consisted of the two-level within-participants factor Blocking Condition (homogeneous: 150 trials, consisting of the first time each of the 25 pictures occurs with each of the three distractor conditions in each blocking condition vs. heterogeneous: 75 trials, accordingly) and the between-participants factor order of Blocking Conditions (homogeneous condition first vs. heterogeneous condition first). As expected, and in replication of prior findings, a significant main effect of Semantic Blocking, $F_1(1, 28) = 6.574$, $MSE = 1338$, $p < .02$ and $F_2(1, 24) = 26.837$, $MSE = 659$, $p <$ 001, revealed faster naming times in homogeneous compared with heterogeneous blocks. The analysis also revealed a highly significant interaction of Semantic Blocking condition and Block Order, $F_1(1, 28) = 41.189$, $MSE = 693$, $p < .001$ and $F_2(1, 24) = 115.495$, $MSE = 914$, $p < .001$. Post hoc comparisons revealed semantically induced facilitation for participants starting with heterogeneous blocks ($M_{\text{diff}} = -90$ msec), $t_1(9) = -5.386$, $p < .005$ and $t_2(24) = -10.207$, $p < .001$, and semantically induced interference for participants starting with homogeneous blocks ($M_{\text{diff}} = 39$ msec), $t_1(19) = 3.372$, $p < .005$ and $t_2(24) = 5.701$, $p < .001$.

This was partially confirmed by a simple between-participants analysis of only the very first naming trials in the experiment (disregarding the distractors with which the objects were paired when named for the very first time in the experiment). This analysis, which comprised just 25 naming trials per participant, included the between-participants factor Start of the Experiment (participants starting with a homogeneous condition, $n = 20$, vs. participants starting with the heterogeneous condition, $n = 10$). This analysis revealed a trend for faster RTs in the group starting with a homogeneous condition ($M = 884$ msec) compared with the group starting with the heterogeneous condition ($M = 956$ msec), $F(1, 28) = 2.11$, $p = .15$.

The observed RT pattern of facilitation and interference effects in the first presentation block will be directly related to the corresponding ERP modulations (see Semantic Facilitation and Interference Effects at Temporal Regions section).

Electrophysiological Results

Overall Blocking and Distractor Effects and Their Interaction

For the ERP results (cf. Figure 2), we first conducted an overall repeated measures ANOVA across all electrodes on mean amplitudes of consecutive 50-msec time windows, starting from the onset of the distractor word (150 msec before target picture onset) until 600 msec after target onset. This analysis included the within-participants factors Electrode (56 levels), Blocking Condition (associatively homogeneous, categorically homogeneous, and heterogeneous), Distractor Relatedness (associatively related, categorically related, and unrelated), and Repetition (one to four). Unless stated otherwise, all effects are reported within the posttarget onset time window. Huyhn–Feldt corrections were applied when appropriate. Because an average reference was used, effects in interaction with electrode site are reported as "main effects" of the corresponding factors only when all electrodes were included in the analysis. For the analyses of topographical distributions, the difference waveforms for each participant were scaled to the individual global field power (McCarthy & Wood, 1985) for each participant.

The results of the overall ANOVA are summarized in Table 3. Specifically, the analysis revealed a main effect of Semantic Blocking between 250 and 400 msec, a main effect of Distractor Relatedness between 200 and 550 msec, and a main effect of Repetition for the entire duration of the analyzed epoch. The effects of semantic blocking and distractor relatedness interacted in four successive time windows between 150 and 350 msec posttarget onset. There was also a Blocking and a Distractor interaction in one isolated early time window (between 50 and 100 msec) that seems too early for semantic effects because the picture had only been processed for 50 msec. One possible

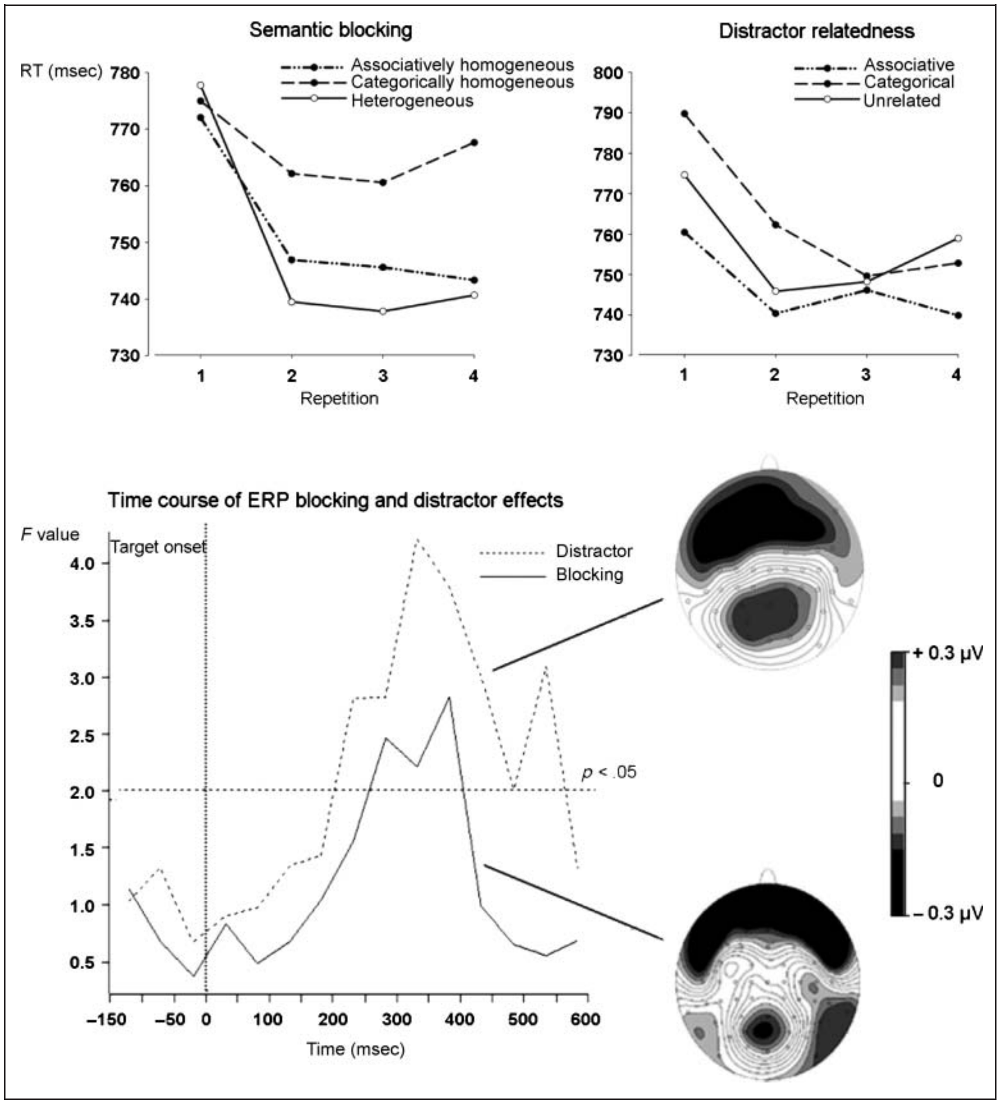

Figure 2. Overall mean RT effects of blocking conditions (top, left) and distractor words (top, right) and an overview of the statistics of overall distractor and blocking effects in event-related brain potentials (bottom).

speculative account of this finding is based on the timing of stimulus presentation. The distractors were presented at an SOA of −150 msec. Thus, they had already been processed for 200 msec when this interaction arose. Possibly, blocking interfered with distractor processing irrespective of the specific picture presented. This might explain why we find this early interaction between distractor and blocking effects here.

There was also a strong effect of Repetition during the entire range of stimulus presentation. However, it did not interact with the Blocking Effects, and it only interacted with the Distractor Effects in two time windows. Thus, repetition does not seem to yield a strong overall modulation of distractor and blocking effects (for a more detailed analysis of the repetition effects, see next section).

Paralleling the investigation of differential interactions between Blocking and Distractor Effects for associative and categorical relations in RTs, we again analyzed the associative and categorical relatedness conditions separately (cf. Figure 3). The factors in each of the two analyses were Blocking Condition (homogeneous and heterogeneous), Distractor Relatedness (related and unrelated), and Electrode (56 levels). For associative relations, the ANOVA revealed a significant interaction between Blocking and Distractor Relatedness starting at 50 msec posttarget onset, $F = 2.869$, $MSE = 5.143$, $p < .03$, which lasted for 400 msec (all Fs > 2). In contrast, for categorical relations, the interaction was confined to a smaller interval, between 250 and 350 msec posttarget onset, $F = 2.4$, $MSE = 4.737$, $p < .05$. This differential pattern is consonant with the RT data, which showed a significant interaction for associative relations but not for categorical relations. The interaction effects between Blocking and Distractor for both types of relatedness are further investigated below. On the basis of previous reports on the loci of semantic context effects (see previous section), two ROIs at frontal and temporal locations were defined for further analyses.

Semantic Interference Effects at Frontal Regions

At frontal regions, visual inspection of the data showed a strong interaction of blocking and distractor effects for both associative and categorical relations (cf. Figure 4). We conducted an analysis with four within-participants factors, Hemisphere (two levels: left and right), Electrode (two levels: F7, FT7 and F8, FT8), Semantic Blocking condition (all three levels), and Distractor Relatedness (all three levels); data from the four repetitions were collapsed. The Semantic Blocking main effect was significant from 250 to 350 msec, all $ps < .05$; smallest $F(2, 58) = 4.342$, largest $p = .017$, and marginally significant in the time window between 200 and 250 msec, $F(2, 58) = 3.032$, $MSE = 1.323$, $p = .056$. The Distractor exerted an influence for a wider time interval, from 150 to 450 msec, all $ps < .05$; smallest $F(2, 58) = 3.224$, largest $p = .047$. From 200 to 450 msec postpicture onset, the interaction of Semantic Blocking and Distractor Condition reached significance, all $ps < .05$; smallest $F(4, 116) = 2.605$, largest $p = .042$. From 150 to 200 msec, the interaction was marginally significant, $F(4, 116) = 2.242$, $MSE = 0.720$, $p = .069$.

Post hoc comparisons revealed that only when both contexts were characterized by the same type of relatedness (i.e., associatively related distractors within an associatively homogeneous block; categorically related distractors within a categorically homogeneous block) did waveforms systematically diverge from all other conditions, but not from each other (smallest $p > .2$). For associative double relatedness, contrasts were significant from 150 to 350 msec, smallest $t(29) = -2.71$, largest $p = .045$, corrected for multiple comparisons. For the categorical double relatedness, mean differences were significant between 200 and 400 msec, smallest $t(29) = -2.58$, largest corrected $p = .052$, although for the contrast with the condition "categorically related distractor within heterogeneous blocks," the difference was marginally significant after correction. Between 300 and 350 msec, categorically related distractors presented within associatively homogeneous contexts showed a marginally significant difference compared with the completely unrelated condition (corrected $p = .062$). No other contrasts revealed significant differences. Contrasts revealed no systematic lateralization effects.

Table 3. Time Course of the Main ERP Effects in the Different Conditions

Time Window (msec)	*Blocking Effect*	*Distractor Effect*	*Repetition Effect*	*Blocking × Distractor*	*Blocking × Repetition*	*Distractor × Repetition*
Pretarget Onset						
150–100	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
100–50	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
50–0	*ns*	*ns*	*ns*	$F = 1.78$**	*ns*	*ns*
Posttarget Onset						
0–50	*ns*	*ns*	$F = 3.46$***	*ns*	*ns*	$F = 1.85$**
50–100	*ns*	*ns*	$F = 1.87$**	$F = 3.09$***	*ns*	*ns*
100–150	*ns*	*ns*	$F = 1.90$**	*ns*	*ns*	*ns*
150–200	*ns*	*ns*	$F = 3.23$***	$F = 2.10$***	*ns*	*ns*
200–250	*ns*	$F = 2.72$***	$F = 3.73$***	$F = 2.76$***	*ns*	*ns*
250–300	$F = 2.38$**	$F = 2.73$***	$F = 9.67$***	$F = 2.00$***	*ns*	*ns*
300–350	$F = 2.12$*	$F = 4.12$***	$F = 6.84$***	$F = 1.89$**	*ns*	*ns*
350–400	$F = 2.73$**	$F = 3.69$***	$F = 5.35$***	*ns*	*ns*	*ns*
400–450	*ns*	$F = 2.91$***	$F = 4.16$***	*ns*	*ns*	*ns*
450–500	*ns*	$F = 1.92$**	$F = 6.09$***	*ns*	*ns*	*ns*
500–550	*ns*	$F = 3.00$***	$F = 6.29$***	*ns*	*ns*	*ns*
550–600	*ns*	*ns*	$F = 9.27$***	*ns*	*ns*	$F = 1.69$*

The reported F values are the results of an ANOVA with electrodes (56 levels), semantic blocking condition (three levels), distractor relatedness (three levels), and repetition (four levels). All values are Huyhn–Feldt corrected.

*$p < .09$.

**$p < .05$.

***$p < .01$.

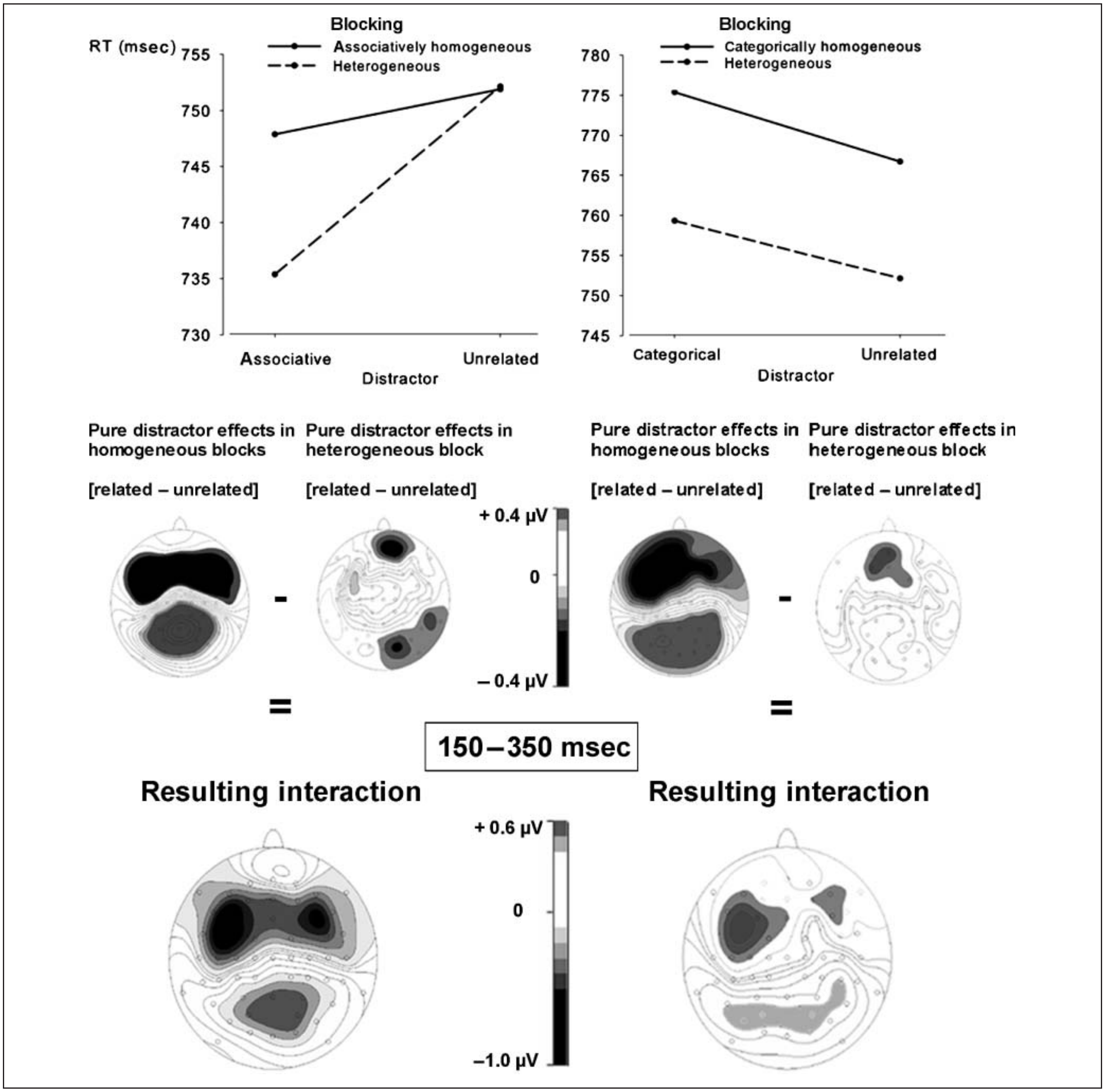

Figure 3. Interactions between blocking and PWI effects for associative relations (left) and categorical relations (right). Top: Mean RTs. Middle: Topographical distributions of the distractor effects in homogeneous and heterogeneous blocks. Bottom: Distributions of the resulting interactions between blocking and distractor effects as differences between distractor effects in homogeneous blocks minus distractor effects in heterogeneous blocks.

Semantic Facilitation and Interference Effects at Temporal Regions

Here, we investigate the ERP modulations produced just for the first repetitions in each block, corresponding to the parallel analysis for RTs (NB: The "first" repetitions of each object in each blocking condition include three presentations of the object, once with all three distractor conditions, see previous section). At temporo-parietal sites (electrode locations TP9 and TP10; cf. Figure 5), ERP modulations directly reflected the semantic facilitation and interference effects observed in RTs as a function of semantic blocking and the order of semantic blocking conditions. Here, behavioral facilitation effects (dominant for the first repetitions in participants starting with the heterogeneous blocking condition) were reflected in a strong bilateral positivity between 200 and 300 msec, whereas interference effects (dominant for the first repetitions in participants starting with one of the homogeneous blocking conditions) were associated with a bilateral negativity in the same time window.

This visual impression was confirmed by an ANOVA with the within-participants factors Semantic Blocking (homogeneous vs. heterogeneous) and Hemisphere (left and right) and the between-participants factor Order of semantic blocking conditions (starting with homogeneous vs. heterogeneous blocking condition), which revealed an interaction of Semantic Blocking and Order of blocking conditions, $F(1, 28) = 7.374$, $MSE = 1.524$, $p < .02$, and $F(1, 28) = 9.344$, $MSE = 1.840$, $p < .005$, for the time windows 200–250 and 250–300 msec, respectively. There was no main effect of Hemisphere (*F*s < 1), but there was a marginally significant interaction between Hemisphere and Semantic Blocking between 250 and 300 msec post-target onset, $F(1, 28) = 3.172$, $MSE = 0.273$, $p = .08$, as well as a three-way interaction of Hemisphere, Semantic Blocking, and Order of blocking conditions between 200 and 300 msec (both *F*s > 3.5). Separate comparisons yielded a significant blocking effect corresponding to the bilateral positivity observed in participants who started with a heterogeneous blocking condition, 200–250 msec, $F(1, 9) = 6.625$, $MSE = 1.321$, $p < .05$ and 250–300 msec, $F(1, 9) = 6.264$, $MSE = 1.679$, $p < .05$, and a marginally significant blocking effect corresponding to the bilateral negativity observed in participants who started with the homogeneous blocking condition within the later time portion, 200–250 msec, $F(1, 19) = 1.626$, $MSE = 1.620$, $p = .218$ and 250–300 msec, $F(1, 19) = 3.513$, $MSE = 1.915$, $p = .076$.

The ERP modulations between 200 and 300 msec suggest that semantic context effects of opposite polarity observed for the first presentation block might be located at the same or highly interactive processing stages and/or

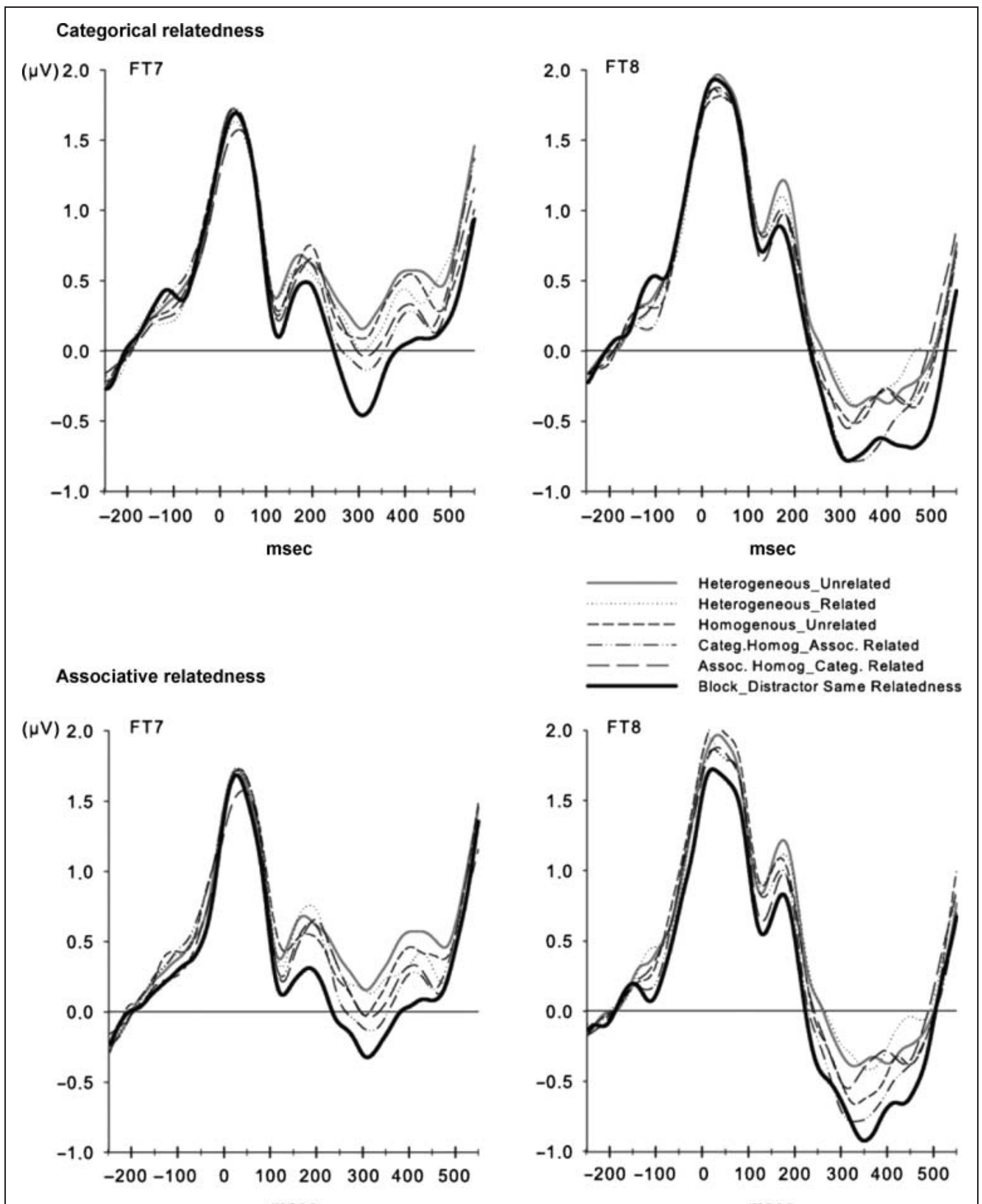

Figure 4. Effects of semantic blocking and distractor type at frontal sites.

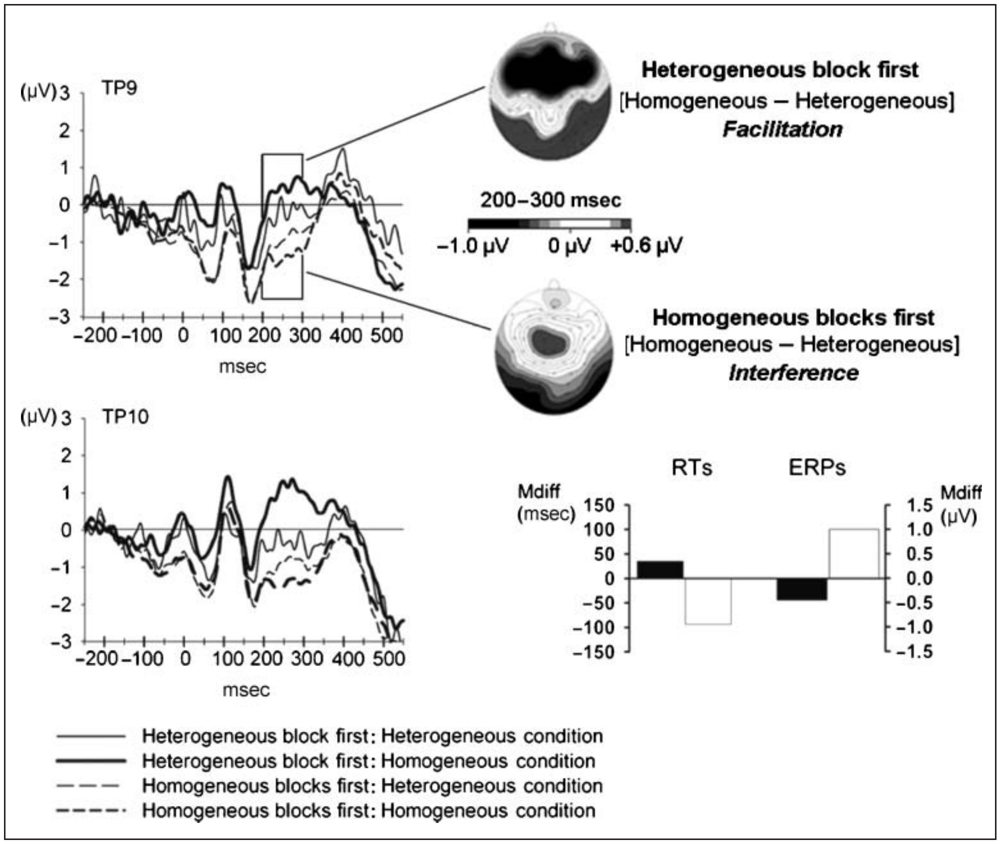

Figure 5. Blocking-induced facilitation and interference effects within the first repetitions as a function of the order of blocking conditions at temporo-parietal electrodes (left). The topographical distributions (middle) depict blocking effects (homogeneous minus heterogeneous) for participants starting the session with heterogeneous or homogeneous blocks, respectively. Bottom right: A direct comparison of blocking effects in mean RTs and mean ERP amplitudes as a function of the order of blocking conditions.

brain regions. This conclusion is further confirmed by a topographical analysis of the distributions of the respective blocking effects (as difference waves between the homogeneous and the heterogeneous blocks for the two groups of participants starting with the homogeneous or heterogeneous blocking condition between 200 and 300 msec; cf. Figure 5). This analysis revealed no topographical differences between the ERP modulations that reflect semantically induced facilitation and interference (Fs < 1).

DISCUSSION

In this study, we investigated the microstructure of semantic context effects during speech production with event-related brain potentials during overt picture naming. We combined two types of frequently used semantic context manipulations, namely, the semantic blocking and the picture–word interference paradigms, and reported distinct ERP modulations for facilitative and inhibitory context effects, thus contributing to the debate on the time course and functional loci of these effects in several ways.

The current report adds to the now growing evidence demonstrating the advantage of combining ERP measures with overt naming. Research on speech production has thus far mostly concentrated on behavioral measures. The majority of prior ERP studies used delayed naming, covert naming, or manual responses to avoid the contamination of the ERP signal by artifacts (cf. Introduction). One shortfall of these approaches is the failure to directly link behavioral effects to ERP components. Without direct evidence that the experimental manipulation produced reliable behavioral effects, interpretation of the ERP signal is limited. A recent development, however, demonstrates growing interest in measuring ERPs while participants overtly speak (e.g., Aristei et al., under revision; Strijkers et al., 2010; Verhoef et al., 2006, 2009; Abdel Rahman & Sommer, 2008; Ganushchak & Schiller, 2008; Hirschfeld et al., 2008; Koester & Schiller, 2008; Verhoef, 2008; Christoffels et al., 2007; Schmitt et al., 2002; Greenham et al., 2000; cf. Introduction).

The present study adds to the rapidly increasing number of studies demonstrating that ERPs and overt articulation can be successfully combined. This allows us to relate classic RT effects from two paradigms to ERP modulations and to track their time course and distribution. Extending the findings reported in the few other recent studies that combine these two measures to investigate semantic context effects induced in the PWI and blocking paradigm during speaking (Ganushchak & Schiller, 2008; Hirschfeld et al., 2008; Schmitt et al., 2002), our study produced reliable ERP modulations that can be directly linked to effects induced by distractor words and semantic blocking as well as to both facilitation and interference effects.

From a methodological point of view, our data revealed the feasibility of EEG registration during overt speaking. Nonetheless, as is usually the case, for every benefit there is some price to pay. In this case and in line with previous reports (e.g., Wohlert, 1993; Brooker & Donald, 1980; Grözinger et al., 1975), caution is recommended when coregistering EEG and overt articulation. First, because the morphology of the speech artifacts in the ERPs seems to vary systematically with the phonetic properties of the utterance, we would recommend comparing experimental conditions in which identical words are produced. This procedure will significantly reduce the danger of interpreting differences because of potential artifacts as experimental effects. Second, at least in the case of producing brief utterances, the influence of speech-related artifacts appears to be largely confined to time periods after the initiation of the utterance. The time interval before articulation does not seem to be irremediably contaminated.

Furthermore, we directly related well-established RT effects in classic speech production paradigms to ERP modulations and track their time course. This latter contribution provides support for previously proposed temporal dynamics underlying the production process as inferred from meta-analyses (Indefrey & Levelt, 2000, 2004). One of the main goals here was to shed light on the functional loci of semantic context effects by assessing the temporal characteristics of ERPs reflecting such effects. The findings will be discussed in the following sections.

Effects of Combining Distractors and Semantic Blocking

The behavioral results reflect the standard naming time patterns observed for categorical and associative distractor words in the PWI paradigm. Categorically related distractors slowed naming, whereas associatively related distractors sped naming, relative to unrelated distractors. The results also replicate established effects observed in the semantic blocking paradigm, namely, slower naming times for categorically and associatively homogeneous compared with heterogeneous blocks. Thus, in line with Abdel Rahman and Melinger's (2007) findings, our results provide converging evidence that the polarity of associative effects is context dependent: Associative relations facilitate naming in the PWI paradigm but hamper naming in the blocking paradigm.

Both manipulations of semantic context produced reliable and temporally overlapping overall ERP modulations: Distractor effects started at 200 msec, and blocking effects emerged with a latency of 250 msec postpicture onset. This time course is in line with the estimated time window of around 150 to 250 msec for conceptually driven lexical access (Indefrey & Levelt, 2004). Because the meta-analysis was mostly based on fMRI, PET, and behavioral studies, only indirect evidence was available for the latter estimate. In line with Maess et al. (2002), the current study thus provides some of the first direct insights into the temporal dynamics of the fine-grained microstructure of semantic context effects in speech production. These initial findings have two implications for our understanding of interference effects: First, the onset of semantic interference effects induced from both PWI and semantic blocking has a similar time course and is thus likely to have the same or similar underlying mechanisms. Second, both effects occur within a time window consistent with a lexical locus. We will return to the theoretical implications of this second point below.

Although several explanations for distractor induced interference effects have been proposed, comparatively little attention has been directed at understanding how interference from semantic blocking arises. Many researchers assume that the same principles underlie distractor and blocking effects (Abdel Rahman & Melinger, 2007; Belke et al., 2005; Damian et al., 2001; Kroll & Stewart, 1994; for an exploration of the underlying mechanism, see Damian & Als, 2005). However, little direct evidence supports this assumption. Here, we show reliable interactions in behavioral and electrophysiological measures when the two paradigms are combined. The overall interaction of distractor and blocking effects in ERPs started at 200 msec postpicture onset. This finding supports the assumption that interference in the two paradigms reflects the same underlying mechanisms, possibly located at the level of lexical selection.

Detailed RT analyses revealed that the interaction was mainly driven by associative relations. Presenting associatively related distractor words in associatively homogeneous blocks eliminates the facilitation observed when the same distractor words are presented in heterogeneous blocks. In contrast, categorically related distractors exert the same influence on naming times regardless of the blocking condition. These effects are partially mirrored in the ERPs: Associative relations produced a strong and long-lasting interaction between distractor and blocking contexts, whereas categorical relations produced a weaker and short-lived interaction. This pattern is consonant with the predictions of the lexical cohort account suggested by Abdel Rahman and Melinger (2007, 2009a).

According to this proposal, RTs are the combined result of conceptual facilitation and lexical competition. Crucially, the activation of a cohort of lexical competitors is a necessary condition for observing measurable interference effects. Categorical and associative relations differ in their natural ability to activate a lexical cohort. Categorical relations, by virtue of sharing several defining features with other members of the category, naturally induce a cohort effect. Hence, embedding a categorical distractor in a categorically homogeneous block does not produce strong interactions because the cohort is activated by the PWI manipulation alone. The situation is different for associative relations. Associatively related pairs tend to not have many shared features, and two associates of a single concept are often themselves unrelated (e.g., whiskers and milk are both associates of CAT but are themselves dissimilar and unassociated). Thus, a single target–distractor pair fails to coactivate a lexical cohort, and thus competition does not overcome conceptual facilitation, resulting in the net facilitation reported in the literature. However, homogeneous blocks convert this typical one-to-one relationship into a more category-like one-to-many situation. Presumably, homogeneous blocks reinforce the common context that interrelates items presented in the block, similar to the creation of an ad hoc category (Barsalou, 1983). The common context thus induces converging activation and lexical cohort competition. In turn, the whole cohort of active lexical competitors generates sufficient competition to detectably slow target selection compared with the condition in which the same distractors are embedded within heterogeneous blocks.

Semantic Context Effects at Frontal Regions

The combination of blocking and PWI manipulations also revealed interactive context effects at frontal regions, apparently driven by the "double matching relatedness" conditions: Frontal ERP modulations were present when the same contexts were established by blocking and distractor manipulations. Specifically, a larger negative going waveform was elicited for categorically related distractors presented in categorically homogeneous blocks and for associatively related distractors presented in associatively homogeneous blocks. In contrast, no difference was found between related and unrelated distractor conditions in heterogeneous blocks or between homogeneous and heterogeneous blocks when the distractors were unrelated to the target or did not match the type of blocking.

This result is in accordance with several reports of semantic context effects at (left) frontal regions (cf. Introduction). That the effect was only present when the same contexts were established by blocking and distractor manipulations might be accounted for in terms of differences in experimental power. The effects might only be strong enough to be detected in the "double matching relatedness" conditions. Functionally, the finding might reflect highly demanding cognitive control or selection processes. For instance, it might be due to a "high-load" condition of selecting targets from among competing semantic alternatives. As discussed in the Introduction, several authors suggest the involvement of the left inferior frontal cortex in semantic selection (e.g., Kan & Thompson-Schill, 2004). Thus, in line with previous neuroimaging data, the double relatedness effect might represent a strong case of such highly demanding selection processes. Alternatively, the results are also in line with suggestions that the frontal activation reflects the detection of response conflicts (e.g., de Zubicaray et al., 2001, 2006; Barch, Braver, Sabb, & Noll, 2000). de Zubicaray et al. (2001, 2006) suggested an involvement of the ACC and pFC in conflict detection and control processes. The authors proposed two mechanisms, conceptual and phonological, which are involved in semantic interference. Semantic/lexical competition is reflected in frontal areas, and phonological competition is associated with activation changes in the middle temporal gyrus. Finally, our results might be interpreted in terms of directing attention to task relevant goals rather than conflict detection (e.g., Roelofs, van Turennout, & Coles, 2006; Roelofs, 2003; for a comprehensive review of control demands during word planning, see Roelofs, 2008). The double matching relatedness condition might induce a high goal-related attentional load condition, thus enhancing frontal (ACC) activation levels. All of the above-discussed mechanisms are in line with our interpretation that the frontal modulations observed here reflect the involvement of executive processes during context-embedded speech production.

Distinguishing Facilitation and Interference at Temporal Sites

The final contribution of this study is the comparison of ERP modulations reflecting facilitation and interference effects. An analysis of the first three repetitions of each picture with all three distractor conditions makes this comparison possible: Blocking-induced facilitation effects in RTs emerged for these first repetitions when the experimental session started with the heterogeneous blocking condition, and interference emerged when the session started with either of the homogeneous conditions. This polarity reversal, which is largely consistent with prior reports (Abdel Rahman & Melinger, 2007), serves as a basis for a comparison of the ERP modulations associated with interference and facilitation.

Facilitation is reflected in an early positive deflection at temporal sites, starting at around 200 msec postpicture onset. Interference is reflected in a negative deflection at temporal sites, emerging slightly later (250 msec post-picture onset). Several theoretical accounts located facilitation at the level of conceptual processing, realized in terms of semantic priming. Our data suggest that participants starting the session with the homogeneous conditions benefit from the meaningful contexts, which facilitate the ease of object identification. In contrast, participants starting the session with the heterogeneous condition cannot make use of semantic cues to aid initial object identification. In line with these assumptions, the early onset of the facilitation effects is in line with a conceptual locus. More specifically, consistent with prior ERP research, this result confirms that basic-level object identification, namely, recognizing an object as a banana (to be distinguished from the earlier process of coarse object classification as, for instance, a fruit or a living thing) occurs between 200 and 300 msec after stimulus presentation (e.g., Scott, Tanaka, Sheinberg, & Curran, 2006; Sehatpour, Molholm, Javitt, & Foxe, 2006; Martın-Loeches, Sommer, & Hinojosa, 2005; Löw et al., 2003; Itier & Taylor, 2002; Doninger et al., 2000; Hinojosa, Martın-Loeches, Gomez-Jarabo, & Rubia, 2000; Martın-Loeches, Hinojosa, Gomez-Jarabo, & Rubia, 1999; Schweinberger, Pfütze, & Sommer, 1995).

Alternatively, the time course of the facilitation effect may also be in line with a localization at the lexical level (e.g., Indefrey & Levelt, 2004). In fact, the amplitude modulations associated with facilitation and interference are temporally overlapping—with a slight temporal advantage of the facilitation effects, associated with conceptual processing, followed after around 50 msec by interference, associated with lexical processing. Furthermore, the effects have similar topographical distributions, albeit with opposite polarities. Although facilitation is associated with a positive deflection at posterior areas and a more central negativity, the opposite distribution was found for interference effects: A negative deflection at posterior areas and a central positivity (this might be due to overlapping networks of neurons firing with a different strength in the case of semantic facilitation and semantic interference, although at a similar time point). The distribution of the facilitation effect is slightly right lateralized, in line with several neuroimaging and neuropsychological studies linking the right (anterior) temporal lobe to semantic processing (e.g., Moore & Price, 1999). In contrast to other empirical observations (e.g., Maess et al., 2002), we did not find a dominance of the left hemisphere for the interference effects.

The close onset and similar scalp distribution of ERPs related to conceptual and lexical processing indicates that object conceptual features and lemma activation can occur in a cascade or parallel manner. This supports the idea of a bidirectional link and a continuous information transmission between semantic and lexical layers in the model of Levelt et al. (1999), which is fundamental for semantic context interference to take place. This is also in line with previous studies showing that phonological encoding and access to semantic properties of the presented object can proceed in parallel (Abdel Rahman & Sommer, 2003; Abdel Rahman et al., 2003).

The discussed pattern of facilitation and interference in ERPs impacts the theoretical debate regarding the locus of semantic interference in picture naming. As discussed in the Introduction, a longstanding view holds that facilitation arises during conceptual processing (realized as a semantic priming due to the coactivation of semantically related items), whereas interference arises as a result of competition between lexical representations that have been activated by their corresponding representations at the conceptual level. Furthermore, the activation flow between conceptual and lexical level is assumed to be bidirectional (Levelt, 1999; Levelt et al., 1999), and the polarity of the context effect will depend on which of the two activations overcomes the other (see Abdel Rahman & Melinger, 2007, 2009a, 2009b). Hence, according to this traditional view, the two effects arise at two interactive and temporally overlapping processing stages (Bloem & La Heij, 2003; Levelt et al., 1999; Caramazza, 1997; Starreveld & La Heij, 1996; Roelofs, 1992; Glaser & Glaser, 1989; La Heij, 1988).

However, recently an alternative proposal has been put forward suggesting that interference effects arise postlexically (Mahon et al., 2007; Finkbeiner & Caramazza, 2006). From this proposal, the prediction can be derived that the time courses of facilitation and interference effects should be distinct and nonoverlapping; facilitation should arise during conceptual or lexical processing at around 200 msec, whereas interference should arise postlexically, between approximately 400 and 600 msec postpicture onset. In the present study, none of the observed context effects had onset latency later than 300 msec postpicture onset. Rather, facilitation and interference effects were strongly overlapping in time, both starting between 200 and 250 msec, and had similar topographical distributions of opposite polarity. Together, these findings suggest that facilitative and inhibitory semantic context effects originate from tightly linked and interacting processing stages relatively early in the planning process. Alternatively, they may even be localized at a common stage (i.e., lexical selection), although it does not seem easy to assign effects of opposite polarity with a highly overlapping time course to a common processing stage. Hence, our findings are not easily reconciled with a late locus for semantic interference, as such a model assumes two different and noninteracting processing stages as functional loci of the respective effects. Instead, the results are in line with the meta-analysis by Indefrey and Levelt (2000, 2004), suggesting conceptually driven lemma selection at around 150 to 250 msec at temporal regions (for further supporting evidence, see also Strijkers et al., 2010).

However, one might argue that although the early onsets of the effects clearly suggest an early locus of interference, additional interference effects at later (postlexical) stages cannot be ruled out. This is because the blocking and the distractor effects are present up to 400 and 550 msec, respectively. Their long durations may effectively mask the onset of later processes. Thus, we cannot exclude the possibility that additional effects arise postlexically. However, it is important to note that no existing theoretical proposal posits two loci for semantic interference and such a proposal, without direct supporting evidence, is not parsimonious. The early onset of our effects supplies direct evidence for an early locus for semantic interference effects, and as of yet, there is no such evidence for similar late effects.

Ideally, a comparison of differential ERP modulations for interference and facilitation effects produced by categorically and associatively related distractor words would have nicely complemented the above argument. Unfortunately, the individual RT effects induced by the distractor types were not reliably reflected in detectable ERP modulations, rendering the further investigation of this interaction with ERPs impossible. Such a comparison could have provided converging evidence regarding the time course of associative facilitation and categorical interference in the PWI paradigm. Similar to the predictions for facilitation and interference effects induced in the first repetitions of the blocking manipulation, the lexical activation account predicts that the two distractor effects have overlapping time courses, whereas the postlexical hypothesis predicts temporally distinct effects. The absence of reliable ERP correlates for specific distractor effects in our study replicates other studies that had similar difficulty (Hirschfeld et al., 2008). As both studies were novel and somewhat exploratory, they may be characterized by conservative analyses (and interpretations) that can lead to "false negatives." Future investigations will hopefully optimize the procedure for combining ERPs and overt naming and in turn be more successful at revealing these specific effects.

To summarize, in line with recent developments, the present study demonstrates the feasibility and informative value of investigating overt speech production with ERPs. Although thus far theories and models of speech production have relied mostly on chronometric data or speech errors, the temporal resolution of ERPs can provide a useful complement to study the microstructure of speaking.

Acknowledgments

This research was supported by grants from the German Research Council to Rasha Abdel Rahman (AB 277 3-1 and 4-1).

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Note

1. Recall that each picture is combined with three types of distractor words and embedded within three semantic blocks. Thus, for this and subsequent analyses, "first repetition" is defined not as the first presentation of a picture within the experiment but rather as the first time a picture is named within a particular semantic context. As such, within each blocking condition, a picture will occur three times at each repetition, once with each type of distractor word; across the experiment, nine naming trials contribute to the first repetitions of a picture.

REFERENCES

Abdel Rahman, R., & Melinger, A. (2007). When bees hamper the production of honey: Lexical interference from associates in speech production. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33,* 604–614.

Abdel Rahman, R., & Melinger, A. (2009a). Semantic context effects in language production: A swinging lexical network proposal and a review. *Language and Cognitive Processes, 24,* 713–734.

Abdel Rahman, R., & Melinger, A. (2009b). Dismissing lexical competition does not make speaking any easier: A rejoinder to Mahon and Caramazza (2009). *Language and Cognitive Processes, 24,* 749–760.

Abdel Rahman, R., & Sommer, W. (2003). Does phonological encoding in speech production always follow the retrieval of semantic knowledge? Electrophysiological evidence for parallel processing. *Cognitive Brain Research, 16,* 372–382.

Abdel Rahman, R., & Sommer, W. (2008). Seeing what we know and understand: How knowledge shapes perception. *Psychonomic Bulletin & Review, 15,* 1055–1063.

Abdel Rahman, R., van Turennout, M., & Levelt, J. W. M. (2003). Phonological encoding is not contingent on semantic feature retrieval: An electrophysiological study on object naming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29,* 850–860.

Alario, F.-X., Segui, J., & Ferrand, L. (2000). Semantic and associative priming in picture naming. *Quarterly Journal of Experimental Psychology, 53A,* 741–764.

Aristei, S., Abdel Rahman, R., Job, R., & Kiefer, M. (under revision). Category-related differences in conditional naming: An ERP study.

Barch, D. M., Braver, T. S., Sabb, F. W., & Noll, D. C. (2000). Anterior cingulated and the monitoring of response conflict: Evidence from an fMRI study of overt verb generation. *Journal of Cognitive Neuroscience, 12,* 298–309.

Barsalou, L. W. (1983). Ad hoc categories. *Memory & Cognition, 11,* 211–227.

Belke, E., Meyer, A. S., & Damian, M. F. (2005). Refractory effects in picture naming as assessed in a semantic blocking paradigm. *Quarterly Journal of Experimental Psychology: Section A, Human Experimental Psychology, 58,* 667–692.

Berg, P., & Scherg, M. (1994). A multiple source approach to the correction of eye artifacts. *Electroencephalography and Clinical Neurophysiology, 90,* 229–241.

Bloem, I., & La Heij, W. (2003). Semantic facilitation and semantic interference in word translation: Implications for models of lexical access in language production. *Journal of Memory and Language, 48,* 468–488.

Bölte, J., Jorschick, A., & Zwitserlood, P. (2003). Reading yellow speeds up naming a picture of a banana: Facilitation and inhibition in picture–word interference. In *Proceedings of the European Cognitive Science Conference, Germany* (pp. 55–60). Mawah, NJ: Lawrence Erlbaum.

Brooker, B. H., & Donald, M. W. (1980). Contribution of speech musculature to apparent EEG asymmetries prior to vocalization. *Brain and Language, 9,* 226–245.

Caramazza, A. (1997). How many levels of processing are there in lexical access? *Cognitive Neuropsychology, 14,* 177–208.

Christoffels, I. K., Firk, C., & Schiller, N. O. (2007). Bilingual language control: An event-related brain potential study. *Brain Research, 1147,* 192–208.

Collins, A. M., & Loftus, E. F. (1975). A spreading activation theory of semantic processing. *Psychological Review, 82,* 407–428.

Costa, A., Alario, F.-X., & Caramazza, A. (2005). On the categorical nature of the semantic interference effect in picture–word interference paradigm. *Psychonomic Bulletin & Review, 12,* 125–131.

Costa, A., Mahon, B., Savova, V., & Caramazza, A. (2003). Level of categorisation effect: A novel effect in the picture–word interference paradigm. *Language and Cognitive Processes, 18,* 205–233.

Damian, M. F., & Als, L. C. (2005). Long-lasting semantic context effects in the spoken production of object names. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31,* 1372–1384.

Damian, M. F., Vigliocco, G., & Levelt, W. J. M. (2001). Effects of semantic context in the naming of pictures and words. *Cognition, 81,* B77–B86.

de Zubicaray, G. I., McMahon, K., Eastburn, M. L., & Pringle, A. (2006). Top–down influences on lexical selection during spoken word production: A 4T fMRI investigation of refractory effects in picture naming. *Human Brain Mapping, 27,* 864–873.

de Zubicaray, G. I., Wilson, S. J., McMahon, K. L., & Muthiah, S. (2001). The semantic interference effect in the picture–word paradigm: An event-related fMRI study employing overt responses. *Human Brain Mapping, 14,* 218–227.

Dell, G. S. (1986). A spreading-activation theory of retrieval in sentence production. *Psychological Review, 93,* 283–321.

Doninger, G. M., Fox, J., Murray, M., Higgins, B., Snodgrass, J. G., Schröder, C., et al. (2000). Activation timecourse of ventral visual stream object-recognition areas: High density electrical mapping of perceptual closure processes. *Journal of Cognitive Neuroscience, 12,* 615–621.

Duncan-Johnson, C. C., & Kopell, B. S. (1981). The Stroop effect: Brain potentials localize the source of interference. *Science, 214,* 938–940.

Finkbeiner, M., & Caramazza, A. (2006). Now you see it, now you don't: On turning semantic interference into facilitation in a Stroop-like task. *Cortex, 42,* 790–796.

Ganushchak, L. Y., & Schiller, N. O. (2008). Motivation and semantic context affect brain error-monitoring activity: An event-related brain potentials study. *Neuroimage, 39,* 395–405.

Glaser, W. R., & Glaser, M. O. (1989). Context effects in stroop-like word and picture processing. *Journal of Experimental Psychology: General, 118,* 13–42.

Greenham, S. L., Stelmack, R. M., & Campbell, K. B. (2000). Effects of attention and semantic relation on event-related potentials in a picture–word naming task. *Biological Psychology, 55,* 79–104.

Grözinger, B., Kornhuber, H. H., & Kriebel, J. (1975). Methodological problems in the investigation of cerebral potentials preceding speech: Determining the onset and suppressing artefacts caused by speech. *Neuropsychologia, 13,* 263–270.

Hantsch, A., Jescheniak, J. D., & Schriefers, H. (2005). Semantic competition between hierarchically related words during speech planning. *Memory & Cognition, 33,* 984–1000.

Hinojosa, J. A., Martın-Loeches, M., Gomez-Jarabo, G., & Rubia, F. J. (2000). Common basal extrastriate areas for the semantic processing of words and pictures. *Clinical Neurophysiology, 111,* 552–560.

Hirschfeld, G. H. F., Jansma, B., Bölte, J., & Zwitserlood, P. (2008). Interference and facilitation in overt speech production investigated with ERPs. *NeuroReport, 19,* 1227–1230.

Indefrey, P., & Levelt, W. J. M. (2000). The neural correlates of language production. In M. Gazzaniga (Ed.), *The new cognitive neurosciences*. Cambridge, MA: MIT Press.

Indefrey, P., & Levelt, W. J. M. (2004). The spatial and temporal signatures of word production components. *Cognition, 92,* 101–144.

Itier, R. J., & Taylor, M. J. (2002). Inversion and contrast polarity reversal affect both encoding and recognition processes of unfamiliar faces: A repetition study using ERPs. *Neuroimage, 15,* 353–372.

Kan, I. P., & Thompson-Schill, S. L. (2004). Effect of name agreement on prefrontal activity during overt and covert picture naming. *Cognitive, Affective, & Behavioral Neuroscience, 4,* 43–57.

Koester, D., & Schiller, N. O. (2008). Morphological priming in overt language production: Electrophysiological evidence from Dutch. *Neuroimage, 42,* 1622–1630.

Kroll, J. F., & Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. *Journal of Memory and Language, 33,* 149–174.

La Heij, W. (1988). Components of Stroop-like interference in picture naming. *Memory & Cognition, 16,* 400–410.

La Heij, W., Heikoop, K. W., Akerboom, S., & Bloem, I. (2003). Picture naming in picture context: Semantic interference or semantic facilitation? *Psychological Science, 45,* 49–62.

Levelt, W. J. (1999). Models of word production. *Trends in Cognitive Science, 3,* 223–232.

Levelt, W. J., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral Brain Science, 22,* 1–38; discussion 38-75.

Liotti, M., Woldorff, M. G., Perez, R., & Mayberg, H. S. (2000). An ERP study of the temporal course of the Stroop color-word interference effect. *Neuropsychologia, 38,* 701–711.

Löw, A., Bentin, S., Rockstroh, B., Silberman, A., Gornolla, A., Cohen, R., et al. (2003). Semantic categorization in the human brain: Spatiotemporal dynamics revealed by magnetoencephalography. *Psychological Science, 14,* 367–372.

Maess, B., Friederici, A. D., Damian, M., Meyer, A. S., & Levelt, W. J. M. (2002). Semantic category interference in overt picture naming: Sharpening current density localization by PCA. *Journal of Cognitive Neuroscience, 14,* 455–462.

Mahon, B. Z., & Caramazza, A. (2009). Why does lexical selection have to be so hard? Comment on Abdel Rahman and Melinger's swinging lexical network proposal. *Language and Cognitive Processes, 24,* 735–748.

Mahon, B. Z., Costa, A., Peterson, R., Vargas, K. A., & Caramazza, A. (2007). Lexical selection is not by competition: A reinterpretation of semantic interference and facilitation effects in the picture–word interference paradigm. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33,* 503–535.

Martın-Loeches, M., Hinojosa, J. A., Gomez-Jarabo, G., & Rubia, F. J. (1999). The recognition potential: An ERP index of lexical access. *Brain and Language, 70,* 364–384.

Martın-Loeches, M., Sommer, W., & Hinojosa, J. A. (2005). ERP components reflecting stimulus identification: Contrasting the recognition potential and the early repetition effect (N250r). *International Journal of Psychophysiology, 55,* 113–125.

McCarthy, G., & Wood, C. C. (1985). Scalp distributions of event-related potentials: An ambiguity associated with analysis of variance models. *Electroencephalography and Clinical Neurophysiology, 62,* 203–208.

Moore, C. J., & Price, C. J. (1999). A functional neuroimaging study of the variables that generate category-specific object processing differences. *Brain, 122,* 943–962.

Moss, H. E., Abdallah, S., Fletcher, P., Bright, P., Pilgrim, L., Acres, K., et al. (2005). Selecting among competing alternatives: Selection and retrieval in the left inferior frontal gyrus. *Cerebral Cortex, 15,* 1723–1735.

Osterhout, L., & Holcomb, P. J. (1995). Event-related potentials and language comprehension. In E. M. D. Rugg & M. G. H. Coles (Eds.), *Electrophysiology of mind*. Oxford: Oxford University Press.

Roelofs, A. (1992). A spreading-activation theory of lemma retrieval in speaking. *Cognition, 42,* 107–142.

Roelofs, A. (2003). Goal-referenced selection of verbal action: Modeling attentional control in the Stroop task. *Psychological Review, 110,* 88–125.

Roelofs, A. (2008). Attention to spoken word planning: Chronometric and neuroimaging evidence. *Language and Linguistics Compass, 2,* 389–405.

Roelofs, A., van Turennout, M., & Coles, M. G. (2006). Anterior cingulate cortex activity can be independent of response conflict in Stroop-like tasks. *Proceedings of the National Academy of Sciences, U.S.A., 103,* 13884–13889.

Schmitt, B., Bles, M., Schiller, N., & Münte, T. F. (2002). *Overt naming in a picture–word interference task analysed with event-related potentials*. 9th annual meeting of the Cognitive Neuroscience Society (CNS), San Francisco, USA.

Schmitt, B. M., Münte, T. F., & Kutas, M. (2000). Electrophysiological estimates of the time course of semantic and phonological encoding during implicit picture naming. *Psychophysiology, 37,* 473–484.

Schmitt, B. M., Schiltz, K., Zaake, W., Kutas, M., & Münte, T. F. (2001). An electrophysiological analysis of the time course of conceptual and syntactic encoding during tacit picture naming. *Journal of Cognitive Neuroscience, 13,* 510–522.

Schnur, T. T., Hirshorn, E., & Thompson-Schill, S. L. (2005). *Mapping semantic interference during picture naming: An fMRI study*. Paper presented at the Cognitive Neuroscience Society, New York.

Schnur, T. T., Lee, E., Coslett, H. B., Schwartz, M. F., & Thompson-Schill, S. L. (2005). When lexical selection gets tough, the LIFG gets going: A lesion analysis study of interference during word production. *Brain and Language, 95,* 12–13.

Schnur, T. T., Schwartz, M. F., Brecher, A., & Hodgson, C. (2006). Semantic interference during blocked-cyclic naming: Evidence from aphasia. *Journal of Memory and Language, 54,* 199–227.

Schriefers, H., Meyer, A. S., & Levelt, W. J. M. (1990). Exploring the time course of lexical access in language production: Picture–word interference studies. *Journal of Memory and Language, 29,* 86–102.

Schweinberger, S. R., Pfütze, E.-M., & Sommer, W. (1995). Repetition priming and associative priming of face recognition. Evidence from event-related potentials. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 722–736.

Scott, L. S., Tanaka, J. W., Sheinberg, D. L., & Curran, T. (2006). A reevaluation of the electrophysiological correlates of expert object processing. *Journal of Cognitive Neuroscience, 18,* 1453–1465.

Sehatpour, P., Molholm, S., Javitt, D. C., & Foxe, J. J. (2006). Spatiotemporal dynamics of human object recognition processing: An integrated high-density electrical mapping and functional imaging study of “closure” processes. *Neuroimage, 29,* 605–618.

Starreveld, P. A., & La Heij, W. (1996). Time course analysis of semantic and orthographic context effects in picture naming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22,* 896–918.

Strijkers, K., Costa, A., & Thierry, G. (2010). Tracking lexical access in speech production: Electrophysiological correlates of word frequency and cognate effects. *Cerebral Cortex, 20,* 912–928.

van Turennout, M., Hagoort, P., & Brown, C. M. (1997). Electrophysiological evidence on the time course of semantic and phonological processes in speech production. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23,* 787–806.

van Turennout, M., Hagoort, P., & Brown, C. M. (1998). Brain activity during speaking: From syntax to phonology in 40 msec. *Science, 280,* 572–574.

Verhoef, K. (2008). *Electrophysiology of language switching in bilingual speakers*. Unpublished doctoral dissertation, Radboud University, Nijmegen, The Netherlands.

Verhoef, K., Roelofs, A., & Chwilla, D. (2006). *Dynamics of language switching: Evidence from event-related potentials in overt picture naming*. CNS meeting, San Francisco.

Verhoef, K., Roelofs, A., & Chwilla, D. (2009). Role of inhibition in language switching: Evidence from event-related brain potentials in overt picture naming. *Cognition, 110,* 84–99.

Wohlert, A. B. (1993). Event-related brain potentials preceding speech and nonspeech oral movements of varying complexity. *Journal of Speech and Hearing Research, 36,* 897–905.