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Selective Inhibition and Naming Performance in Semantic Blocking, Picture-Word Interference, and Color–Word Stroop Tasks

Zeshu Shao
Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands

Ardi Roelofs
Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands, and Radboud University

Randi C. Martin
Rice University

Antje S. Meyer
Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands, and Radboud University

In 2 studies, we examined whether explicit distractors are necessary and sufficient to evoke selective inhibition in 3 naming tasks: the semantic blocking, picture–word interference, and color–word Stroop task. Delta plots were used to quantify the size of the interference effects as a function of reaction time (RT). Selective inhibition was operationalized as the decrease in the size of the interference effect as a function of naming RT. For all naming tasks, mean naming RTs were significantly longer in the interference condition than in the control condition. The slopes of the interference effects for the longest naming RTs correlated with the magnitude of the mean interference effect in both the semantic blocking task and the picture–word interference task, suggesting that selective inhibition was involved to reduce the interference from strong semantic competitors either invoked by a single explicit competitor or strong implicit competitors in picture naming. However, there was no correlation between the slopes and the mean interference effect in the Stroop task, suggesting less importance of selective inhibition in this task despite explicit distractors. Whereas the results of the semantic blocking task suggest that an explicit distractor is not necessary for triggering inhibition, the results of the Stroop task suggest that such a distractor is not sufficient for evoking inhibition either.

Keywords: selective inhibition, picture–word interference, semantic blocking, Stroop

To communicate effectively in everyday life, speakers must select the right words at the right time. A key component of word production is *lexical access*, that is, the retrieval of words from the mental lexicon given the concepts to be expressed. Lexical access has been widely studied, and this research effort has led to the development of detailed models of the linguistic encoding processes involved in lexical access (e.g., Caramazza, 1997; Dell, 1986; Levelt, Roelofs, & Meyer, 1999; Rapp & Goldrick, 2000). Word production is a goal-directed activity, as speakers typically aim to achieve a communicative goal with their utterances. Therefore, the question arises of how the processes of lexical access interface with cognitive control processes so that speakers usually do not emit just any words but words serving their intentions (e.g., Roelofs, 2003, 2014).

One of the reasons why selecting the right word at the right time is not trivial is that often several concepts and the associated words are simultaneously active in the speakers' mind. The competing concepts and words can, for instance, pertain to related ways of thinking about the same object (e.g., *sofa* vs. *couch*), to objects to be referred to in succession in a sentence (which can lead to anticipatory speech errors, such as "throw the window through the clock," Fromkin, 1971), to objects just mentioned by an interlocutor, or to different names associated with a single object in the mind of a multilingual speaker.

There is accumulating evidence pointing to an important role of inhibitory processes during lexical selection. For instance, it has been proposed that bilingual speakers use inhibition to suppress their nontarget language whenever they speak or listen to speech (e.g., de Bruin, Roelofs, Dijkstra, & FitzPatrick, 2014; Guo, Liu, Misra, & Kroll, 2011; Jackson, Swainson, Cunnington, & Jackson, 2001; Misra, Guo, Bobb, & Kroll, 2012; Roelofs, Piai, & Garrido Rodriguez, 2011). There is also evidence that deficits in inhibition ability may contribute to the impaired word production of children with specific language impairment (e.g., Henry, Messer, & Nash, 2012; Im-Bolter, Johnson, & Pascual-Leone, 2006; Seiger-Gardner & Schwartz, 2008; Spaulding, 2010). Most important for the present purposes, the results of several studies suggest the involvement of general inhibitory control when adults name objects in their first language (Belke & Stielow, 2013; Crowther & Martin, 2014; de Zubicaray, McMahon, Eastburn, & Pringle, 2006; de

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Zeshu Shao, Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands; Ardi Roelofs, Max Planck Institute for Psycholinguistics and Donders Institute for Brain, Cognition and Behaviour, Radboud University; Randi C. Martin, Department of Psychology, Rice University; Antje S. Meyer, Max Planck Institute for Psycholinguistics and Donders Institute for Brain, Cognition and Behaviour, Radboud University.

Correspondence concerning this article should be addressed to Zeshu Shao, P.O. Box 310, 6500 AH Nijmegen, The Netherlands. E-mail: zeshu.shao@mpi.nl

Zubicaray et al., 2001; Shao, Meyer, & Roelofs, 2013; Shao, Roelofs, Acheson, & Meyer, 2014; Shao, Roelofs, Meyer, 2012).

However, there is disagreement regarding the concept of inhibition. Some authors distinguish different components of inhibition supporting response selection in different types of conflicting situations (Miyake et al., 2000; Nigg, 2000). It is unclear which component of inhibition is involved in word production. In the present study, we are interested in two components of top-down inhibitory control (e.g., Castner et al., 2007; Forstmann et al., 2008a; Forstmann, van den Wildenberg, & Ridderinkhof, 2008b; Krämer, Knight, & Münte, 2011; Spaulding, 2010). One component is called response suppression or *nonselective inhibition* and serves to suppress the execution of planned actions. This type of inhibition is considered to be nonselective because it is applied to stop any incorrect or inappropriate response. Nonselective inhibition is often assessed using the stop-signal task (Logan & Cowan, 1984), where participants prepare for a response but have to refrain from executing it on presentation of a stop signal. The timing of the stop-signal varies across trials depending on the participant's performance on the preceding trials. The time participants can stop their responses (i.e., the stop-signal RT: SSRT) is used as an indicator of nonselective inhibition ability.

Another component of inhibition is referred to as interference control or *selective inhibition*, as proposed by the activation-suppression hypothesis (Ridderinkhof, 2002). This type of inhibition is specifically recruited to lower the activation of strong competitors to a target response. The effects of selective inhibition can be seen in tasks such as the Simon or Eriksen flanker task, where strongly competing responses are induced by distractors in an incongruent condition but not in a congruent condition. An important characteristic of selective inhibition is that it takes time to be applied (e.g., Forstmann et al., 2008a, 2008b; Ridderinkhof, 2002; Ridderinkhof, Scheres, Oosterlaan, & Sergeant, 2005; see Proctor, Miles, & Baroni, 2011; Van den Wildenberg et al., 2010, for reviews). Consequently, the effect of selective inhibition should be more pronounced on slower than on faster responses. The dynamics of applying selective inhibition can be revealed through RT distribution analyses, such as *delta plots*. Delta plots are constructed by calculating the RT difference between competing and noncompeting conditions as a function of RT (de Jong et al., 1994; Ridderinkhof, 2002; see below for details). Specifically, the size of the RT difference (i.e., delta) is plotted by first dividing the rank-ordered RTs for each condition into quantiles (e.g., quintile or 20% bins) and then plotting the size of the interference effect (delta) for each quantile. When no selective inhibition is applied, the size of the RT difference, expressed by the slope of the line connecting successive quantile means, increases across quantiles. Thus, slower reactions are accompanied by larger RT differences and slopes. When selective inhibition is applied, the interference effect is attenuated, and, importantly, more so for slower than for faster responses due to the time required for applying selective inhibition. Therefore, the slope for the slowest naming RT segment (e.g., from the fourth to the fifth quintile mean) can be used to estimate an individual's inhibition ability. The delta plot slopes for successive quantiles x and y are computed as follows (cf. Ridderinkhof, 2002): slope $(x, y) = \delta$ (quantile y) – delta (quantile x)/mean (quantile y) – mean (quantile x).

Delta plots have been used in many nonlinguistic studies to index the time course of suppressing conflicting responses. Forstmann et al. (2008a) studied the neural bases and temporal dynamics of selective inhibition in the Simon task, where participants have to select between two competing responses. Using fMRI, they found a strong negative correlation between the activation of right inferior frontal cortex and the slope of the slowest delta segment, indicating that participants who were good inhibitors, compared to poor inhibitors, had more pronounced neural signal change and more negative going slopes. Similarly, Wylie and colleagues (2009) compared performance between people with Parkinson's disease (PD) and healthy controls in the Simon task and found that the slope of the slowest delta segment was more negative going for the healthy controls than for the PD patients. This suggests that PD patients had less effective inhibition than did healthy controls. For further discussion and a review of the empirical support of these assumptions about delta-plot slopes and selective inhibition we refer to Burle et al. (2002); Forstmann et al. (2008a, 2008b); Proctor et al. (2011); Ridderinkhof et al. (2005); Van den Wildenberg et al. (2010); and Wylie et al. (2009).

In two earlier studies, we examined whether we could separate the contributions of selective and nonselective inhibition to picture naming. In the first study (Shao et al., 2012), speakers named pictures of objects and actions and performed the stop-signal task, which assesses nonselective inhibition. Analyses of the correlations of the participants' speed in the three tasks suggested that nonselective inhibition was involved (i.e., the naming RTs and SSRT were positively correlated) in both action and object naming (both $rs = .45$).

In the second study (Shao et al., 2013), we used a picture–word interference task, which required participants to name target pictures in the presence of semantically related or unrelated distractor words (e.g., a picture of a cat with the distractor words *dog* or *pen*, respectively). A robust finding in this paradigm is that the mean naming RT is longer in the semantically related than in the unrelated condition (e.g., Damian & Martin, 1999; Glaser & Düngelhoff, 1984; Roelofs, 2003; Schriefers, Meyer, & Levelt, 1990). The origin of this semantic interference effect is still under debate. One explanation is that it arises early during the name planning process, namely during the selection of an appropriate lexical item: Semantically related distractors receive extra activation from the pictures and therefore compete more strongly with the targets than unrelated distractors (see Roelofs, 1992, 2003, for details). Another explanation is that the effect arises late (i.e., after response planning), during an articulatory buffering stage: The written distractor word activates the associated articulatory program, which is entered into an output buffer. The articulatory program activated in response to the distractor word must be removed from the output buffer so that the articulatory program for the response to the target picture can be executed. This is assumed to take longer when target and distractor are semantically related than when they are unrelated (e.g., Finkbeiner & Caramazza, 2006; Mahon, Costa, Peterson, Vargas, & Caramazza, 2007). Both accounts assume that semantically related distractors generate more interference than unrelated ones. One might therefore expect selective inhibition to be applied specifically to related distractors.

In the picture–word interference task used in Shao et al. (2013), we found longer naming latencies in the semantically related than in the unrelated condition, as expected. More important, when we examined the magnitude of the interference effect as a function of response speed by performing delta plot analyses, we found that the mean size of the participants' interference effects was predicted well by the slope of the delta plot for the slowest RTs. In other words, participants with good selective inhibition (expressed as a shallow slope of the slowest segment of the delta plot) showed a smaller mean interference effect than participants with poorer selective inhibition (expressed as a steeper slope). In addition to the picture–word interference task, the participants carried out the stop-signal task. We found that their performance in this task was correlated with their naming RT in the unrelated condition (and the average across both distractor conditions) of the picture–word interference task (r = .32), but not with the slopes of the slowest segments of the delta plot (r = .02). This demonstrates that selective and nonselective inhibition can be dissociated to some extent.

In the picture–word interference paradigm, varying amounts of interference are induced by distractor stimuli that are presented at the same time as the targets. An important question is whether these explicit distractors are necessary to evoke selective inhibition in naming, or whether inhibition may also be triggered without explicit distractors. Moreover, it is unclear whether explicit distractors are sufficient to evoke selective inhibition in naming. In the present study, we investigated whether selective inhibition would also be recruited in a naming task without overt distractor stimuli, when strongly competing responses are activated through the prior experience of the participant in the task. This is important for understanding the role of selective inhibition in naming, but also more generally for refining the concept of selective inhibition. All earlier studies of selective inhibition we know of induced different degrees of competition among responses by presenting different types of visual stimuli, which either did or did not feature distracting information. For instance, in the Simon task the stimuli (e.g., a circle and a square) are presented on the right-hand or left-hand side of a computer screen, and participants have to respond to the stimuli (e.g., the circle) by pressing the left or right response button (e.g., left for circle and right for square). The reactions are faster for stimuli appearing on the same side as the correct response button (e.g., left side for circles) than for stimuli appearing on the opposite side, even though the stimulus location is irrelevant to the task. Similarly, in the Eriksen flanker task participants have to respond to a letter (e.g., S or H) that is flanked by distractor letters on each side (e.g., incongruent SSHSS or congruent SSSSS). The average RT is longer in the incongruent than the congruent condition. Studies of selective inhibition using the Simon or Eriksen flanker tasks found that interference was reduced for relatively longer, compared to shorter, RTs. In particular, for the participants with more efficient inhibition ability, the delta plots which are positive going for short RTs become flat or even negative going when RT gets longer (for the Simon task, see De Jong et al., 1994; for the Eriksen flanker task, see Wylie et al., 2009). In these tasks, as in the picture–word interference task, conflict was introduced by a mismatch between relevant and irrelevant stimulus dimensions.

In the present study, we examined whether selective inhibition is recruited in picture naming when strongly competing responses are activated in the absence of overt distracting information. To this end, we used the semantic blocking paradigm (e.g., Belke, Meyer, & Damian, 2005; Damian, Vigliocco, & Levelt, 2001; Kroll & Stewart, 1994; Schnur et al., 2009). In this paradigm, participants repeatedly name small sets of objects. In homogeneous test blocks, all objects belong to the same semantic category (e.g., they are all animals or they are all vehicles). In heterogeneous test blocks, they belong to different categories. A robust finding is that participants are slower to name the objects in homogeneous than in heterogeneous blocks. This semantic context effect probably arises during the selection of the object name: In related sets, the object names activate each other (perhaps via shared features or links to a shared category node), which delays the selection of the object names, compared to the unrelated sets, where the items do not activate each other (Abdel Rahman & Melinger, 2007; Belke, 2008; Belke et al., 2005; Damian et al., 2001; Kroll & Stewart, 1994; see Oppenheim, Dell, & Schwartz, 2010, for a slightly different view). Thus, the cause of the semantic blocking effect may be similar to that of the semantic interference effect, namely competition between semantically related concepts or the associated words. If selective inhibition is invoked in naming whenever there are strongly competing responses (i.e., if explicit distractors are not necessary to trigger inhibition), there should be evidence for its engagement in the semantic blocking task. By contrast, if selective inhibition is only involved when speakers deal with a specific physically present distractor word (as in picture–word interference), no such evidence should be seen.

In Study 1, the same group of participants was tested in three naming tasks and performed the stop-signal task. The first naming task was picture–word interference (e.g., Glaser & Düngelhoff, 1984; Schnur & Martin, 2012), similar to the task used in Shao et al. (2013), but using new materials. We expected to replicate the pattern seen in this earlier study: There should be a semantic interference effect, the size of which should correlate with the participants' selective inhibition ability, indicated by the slope of the delta plot for their slowest responses. Furthermore, the participants' performance on the stop-signal task should correlate with their naming RT in the unrelated condition, but not with the size of the semantic interference effect.

In the second naming task, we used the semantic blocking paradigm. The same pictures were used as in the picture–word interference task to ensure that the comparison between the two tasks was uncontaminated by differences in materials. We expected to obtain a semantic blocking effect, that is, longer picture naming RTs in the semantically related (homogeneous) sets than in the unrelated (heterogeneous) sets. If selective inhibition is engaged in this task (i.e., if explicit distractors are not necessary to trigger inhibition), the mean size of the participants' interference effect should depend on their inhibition ability. We should then again obtain a correlation between the mean effect sizes and the slopes of the delta plot for the slowest RTs. Furthermore, the effect sizes and slopes should not correlate with the performance on the stop-signal task, which is a measure of nonselective inhibition.

Finally, in the third naming task, we used the classic Stroop task, in which participants name the color in which congruent or incongruent color words or a row of hash marks (i.e., #####) is printed. The Stroop task is often considered as a prototypical interference task (e.g., Glaser & Glaser, 1982; Roelofs, 2003). This task is often seen to be closely related to the picture–word interference task, as it also involves the selection of a target (the name of the color of the ink) in the presence of a potent competitor (the color word, e.g., Roelofs, 2003). However evidence for the involvement of selective inhibition as reflected by the slope of the slowest delta segment in the Stroop task is inconsistent. For instance, Bub, Masson, and Lalonde (2006) found that younger children had a shallower slope of the slowest delta segment than had older children in the Stroop task, suggesting that younger children applied more inhibition to word reading than older children. However, Soutschek et al. (2013) found that both people with ADHD (who were assumed to have an inhibition deficit) and healthy controls showed similar slopes of delta segments in the Stroop task. In contrast, Pratte et al. (2010) found an increased Stroop effect with longer RTs, suggesting that inhibition was not applied. Thus, the dynamics of applying selective inhibition in the Stroop task varies between studies, suggesting that the Stroop interference effect may not only be affected by response competition but also by other factors, such as perceptual conflict (van den Wildenberg et al., 2010). Another possibility is that the use of inhibition is optional (cf. Roelofs et al., 2011; Verhoef, Roelofs, & Chwilla, 2009), which means that selective inhibition is not necessarily applied to resolve response conflict in the Stroop task.

If the presence of explicit distractors is sufficient for triggering selective inhibition, one would expect selective inhibition to be involved in the Stroop task (Bub et al., 2006; Sharma et al., 2010). Consequently, one should see similar results for the Stroop task as for the picture–word interference task: There should be an interference effect, the size of which should depend on the participants' inhibitory control ability, indexed by the slope of the slowest segment of the delta plots. In contrast, if the presence of explicit distractors is not sufficient for triggering selective inhibition, and selective inhibition does not need to be involved in the Stroop task (Lamers et al., 2010; Pratte et al., 2010), the magnitude of the mean interference effect in the Stroop task may not correlate with the slope of the slowest delta segment.

Given that the same group of participants was tested in all tasks, we could explore the consistency of their performance across tasks. If similar processing mechanisms are involved in all three tasks, high correlations between the effect sizes and slopes of the delta plots should be seen. However, the evaluation of the correlations is somewhat complicated by the fact that the two picture-naming tasks used the same materials, whereas different materials were used in the Stroop task. To evaluate the effects of the shared set of pictures, Study 2 was run using different items in the two picture-naming tasks.

Study 1

Method

Participants. The study was carried out with 25 undergraduate or postgraduate students (nine men, mean age = 21.16 years, range: 18 to 27 years). They were recruited from the participant pool of the Max Planck Institute for Psycholinguistics, Nijmegen. All participants were native speakers of Dutch and had normal or corrected-to-normal vision and normal hearing. They were paid for their participation.

The participants were tested individually. Half of the participants carried out the semantic blocking task first, followed by the Stroop task, the picture–word interference task, and the stop-signal task; and the other half began with the picture–word interference task, followed by the stop-signal task, the semantic blocking task, and the Stroop task. Thus, in both groups, the two picture-naming tasks were separated by the Stroop and stop-signal tasks. There were short breaks between the tasks.

Semantic blocking task.

Materials and design. The materials consisted of 16 line-drawings of common objects adopted from the Snodgrass and Vanderwart (1980) corpus, drawn from four categories (animals, furniture, tools, and body parts, listed in the Appendix). All picture names were monosyllabic. The average log-word-form frequency in the SUBTLEX-NL database was 1.52 /million (SD = 0.73), and the average age of acquisition was 5.5 years (SD = 1.60 years; Ghyselinck, De Moor, & Brysbaert, 2000). All drawings fitted into a virtual frame of 4 cm by 4 cm (2.29° of visual angle) and were shown on a white background in the center of the computer screen.

There were four homogeneous and four heterogeneous sets of pictures. Each homogeneous set featured the four members of one of the four semantic categories. Each heterogeneous set featured one member of each category. The picture names in a set were unrelated in phonological form, sharing neither the onset nor the rhyme. Each of the eight sets was tested in a separate test block. In each block, the four items were shown six times each in a cyclic fashion, that is, the four items were shown once, then they were all shown again for a second time, then for a third time, and so on. In generating the test cycles care was taken that the last item of a cycle was not the same as the first item of the next cycle. During the task, homogeneous and heterogeneous blocks alternated. Their order was counterbalanced across participants according to a Greco-Latin square design.

Procedure. At the beginning of the task, the participants were given a booklet showing the pictures and corresponding names. They were asked to familiarize themselves with the materials and to use only the names in the booklet to refer to the pictures. Then they were handed a second booklet showing only the pictures and were asked to name them. Any errors were corrected by the experimenter. This training continued until the participants had named all pictures once without making an error. The familiarization phase was omitted in the group of participants who had already performed the picture–word interference task.

On each trial of the test blocks, a fixation cross (+) was presented for 300 ms in the center of the screen. After a blank interval of 200 ms, a picture was presented until the participant responded, for a maximum of 3,000 ms. The intertrial interval was 1,000 ms.

Data analyses. Responses were categorized as errors when participants used different names from those given in the picture booklet or when the response included a repair or disfluency. Errors were excluded from the analyses of naming latencies.

Apparatus. All tasks were administered using a HP 8540P laptop. The Presentation® software package (Version 14.3, www.neurobs.com) was used to control the task. Naming RTs were recorded online using a voicekey but were later manually corrected using the speech analyses program Praat (Boersma, 2001).

Picture–word interference task.

Materials and design. The same 16 pictures were used as in the semantic blocking task. The distractor words were the names of the pictures. The same linguistic materials were used in both tasks so that the two tasks only differed in whether or not distractors were physically present (as written words) during the object naming task. The distractors were superimposed in the center of the pictures and presented in black in lowercase, 26-point Arial font.

There were two conditions, featuring semantically related or unrelated distractor-target pairs. Each of the 16 pictures was shown six times in each condition. In the semantically related condition, each picture was combined with the names of each of the other three members of the same category. In the unrelated condition, each picture was presented in combination with three different unrelated distractors (one from each of the three nontarget semantic categories). In total, the task consisted of 192 trials, distributed across four test blocks of 48 trials each. Across all test blocks, each object name was used three times as a related distractor and three times as an unrelated distractor. The items were pseudorandomized to make sure that the same item or the same distractor did not occur on successive trials. The order of the four test blocks was rotated across participants. Note that the two naming tasks were matched for number of trials, and in each task each item was tested six times each in the semantically related and in the unrelated condition.

Procedure. The participants were first familiarized with the materials as described above. The familiarization phase was omitted in the group of participants who had already carried out the semantic blocking task. On each trial of the test blocks, a fixation cross (+) was presented for 300 ms in the center of the screen. After a blank interval of 200 ms, a target–distractor compound was shown until the participant responded, for a maximum of 3 s. The intertrial interval was 1,000 ms.

Stroop task.

Materials and design. The stimuli consisted of three Dutch color words, BLAUW (blue), GROEN (green), and ROOD (red), and a string of hash marks (i.e., #####) printed in one of the three colors blue, green, and red. There were three conditions: congruent, incongruent, and neutral. In the congruent condition, the words were presented in the corresponding color (e.g., ROOD printed in red ink); in the incongruent condition, the words were presented in a different color (e.g., GROEN presented in red ink); and in the neutral condition, the symbol string was presented in one of the three colors. Each color was presented eight times in each condition, which led to a total of 24 trials in each condition. The stimuli were presented in lowercase, 66-point Lucida Console font.

On each trial, a fixation cross was presented in the screen center for 500 ms, followed by the stimulus word or string for 1,000 ms. Then a black screen was presented until the participant responded, for up to 2,000 ms. Participants were instructed to name the color of the ink as quickly as possible. Incorrect responses were excluded from the RT analyses. The naming RT difference between the incongruent and neutral conditions was used to index the strength of the Stroop interference effect.

Stop-signal task.

Materials, design and procedure. The visual stimuli were a fixation cross, a square (1.5 by 1.5 cm), and a circle (1.5 cm in diameter). The auditory stimulus was a 750 Hz tone with a duration of 75 ms.

On go-trials, the fixation cross (+) was presented in the middle of the screen for 250 ms and was immediately replaced by a square or a circle for a maximum of 1,250 ms. Squares and circles were presented equally often in a random order. The participants should press the "/" key when they saw a circle and the *Z* key when they saw a square. They were instructed to respond as quickly as possible. The key press terminated the trial. On stop-trials, the tone was played as a stop-signal shortly after the offset of the fixation cross. The participants were instructed to withhold their response when they heard the tone. The stop-signal delay (SSD) was initially set to 250 ms after the offset of the fixation cross. If the participant successfully inhibited the response on a given stop trial, the SSD on the following stop trial was increased by 50 ms, otherwise it was reduced by 50 ms.

There was a practice block of 32 trials, followed by three test blocks of 64 trials each. Each block included 75% go-trials and 25% stop-trials, presented in a random order. Following Verbruggen et al. (2008), each participant's stop-signal RT (SSRT) was estimated by subtracting the mean stop-signal delay across all trials from the mean RT on go-trials. Short SSRTs indicate that participants can stop their responses relatively late during response preparation and are indicative of good inhibitory control.

Results and Discussion

The data obtained from one participant were lost due to technical problems. Table 1 summarizes the error rates and RTs for the remaining participants in all tasks.

Semantic blocking task. Log-transformed naming RTs of the semantic blocking task were submitted to mixed-effects model analysis (Quené & van den Bergh, 2008) using the software package R (R Development Core Team, 2011). Fixed effects were blocking context, trial number, and task order, and random effects included random intercept for participants and items, and random slope of blocking context for participants and items. The results showed a significant main effect of blocking context, $t = 3.98$ (an effect was judged as significant when the absolute t-value exceeded 2; Baayen, Davidson, & Bates, 2008), with the average naming RT being longer (by 24 ms) in the homogeneous than in the heterogeneous condition. But there was no main effect of trial number or task order (ts < 0.75). Then we replaced trial number by cycle number and reran the mixed-effects model analysis. A main effect of cycle number was found ($t = -3.88$; see Figure 1), indicating that the naming RTs decreased across cycles within each block (by 4 ms). There was no interaction of blocking context and cycle ($t = 0.18$). This is an unexpected finding because earlier studies have shown that the blocking effect takes at least one cycle to build up. Error rates were analyzed using mixed logit models

Table 1
Mean Reaction Time (in Milliseconds) and Error Rate per Condition for the Semantic Blocking (SB) Task, the Picture–Word Interference (PWI) Task, the Stroop Task, and Go-Trials of the Stop-Signal Task for Study 1

		Reaction time		Error rate (%)	
Task	Condition	*M*	*SD*	*M*	*SD*
SB	Homogeneous	576	55	6.7	6.0
	Heterogeneous	552	48	5.9	5.2
PWI	Related	688	82	2.0	1.6
	Unrelated	662	67	1.0	1.4
Stroop	Incongruent	818	138	5.2	4.0
	Congruent	682	109	2.5	3.9
	Neutral	658	87	2.5	4.8
Stop-signal	Go trials	611	164	2.1	2.3

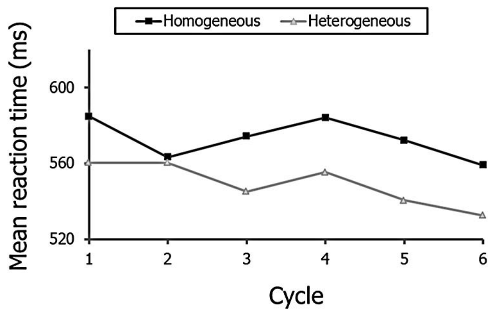

Figure 1. Mean naming reaction time (RT; in milliseconds) in the semantic blocking task over cycles, broken down by blocking context.

(Jaeger, 2008). There was no main effect of blocking context, trial number/cycle number, or task order (zs < 1.53, ps $> .10$).

To quantify the relationship between the strength of the interference effect on the naming RTs and the participants' selective inhibition ability, we computed the correlations between the slopes of the slowest delta segment and the magnitude of the mean interference effect for each participant. In line with our prediction, we found a significant correlation ($r = .42$, $p < .01$), indicating that individuals with poorer selective inhibition (i.e., a steeper slope) showed a larger context effect (see Footnote 1). Figure 2A shows the corresponding scatter plot. According to the activation-suppression hypothesis (Ridderinkhof, 2002), selective inhibition needs time to build up and therefore it is expected to be more strongly reflected by slower than faster responses. To examine this prediction, we assessed the correlation between the slopes of the fastest delta segment and the magnitude of the mean interference effect for each participant. We found no significant correlation ($r = .12$, $p = .58$). This suggests that selective inhibition is especially reflected in the slope of the slowest delta segment, in line with earlier empirical evidence (e.g., Forstmann et al., 2008a).

Picture–word interference task. As for the semantic blocking task, log-transformed naming RTs of the picture–word interference task were submitted to mixed-effects model analysis. The fixed effects were distractor condition, trial number and task order; the random effects included random intercept for participants and items and random slope of distractor condition for participants and items. There was a significant main effect of distractor condition ($t = 3.49$), with the average naming RT being longer (by 26 ms) in the semantically related than in the unrelated condition. But there was no main effect of trial number or task order (ts < 1.03). Error rates were analyzed using mixed logit models. There was a significant main effect of distractor condition ($z = -2.55$, $p < .01$), with participants making more errors in the semantically related than in the unrelated condition (see Table 1).

As for the semantic blocking task, we assessed the correlation between the slopes of the slowest delta segment and the magnitude of the mean interference effect for each participant. We found a significant correlation ($r = .75$, $p < .001$). Figure 2B shows the corresponding scatter plot. As with the semantic blocking task, the positive correlation suggests that individuals with poorer selective inhibition showed a larger semantic interference effect. We found no correlation between the slope of the fastest delta segment and the magnitude of the mean interference effect for each participant ($r = .09$, $p = .69$).

Stroop task. Log-transformed naming RTs of the Stroop task were submitted to mixed-effects model analysis. The fixed effects were condition (congruent, neutral, and incongruent) and trial number. The random effects included random intercept for participants and random slope of condition for participants. Naming RTs in the neutral condition were significantly shorter than naming RTs in both the congruent condition ($t = 2.3$) and incongruent condition ($t = 13.1$). The results show the typical Stroop interference effect in that participants were slower to name the color of ink when the stimulus was an incongruent color word than when it was a row of hash marks. The error rates were analyzed using mixed logit models. There were more errors in the incongruent condition than in the neutral condition ($z = 3.38$, $p < .01$). Error rates in the congruent condition were not significantly different from those in the neutral condition ($z = 1.06$, $p = .26$). In general, error rates decreased across trials ($z = -2.85$, $p < .01$).

Delta plots were computed as for the two picture-naming tasks, though tertiles of naming RTs were used instead of quintiles because fewer observations were available (cf. Forstmann et al., 2008a). There was no correlation between the size of the Stroop interference effect (i.e., RT difference between incongruent and neutral condition) and the slope of the delta plot for the slowest reactions [$r = -.02$], suggesting that participants' selective inhibition ability was unrelated to the magnitude of their Stroop effect. Figure 2C shows the corresponding scatter plot. There was also no correlation between the size of the Stroop interference effect and the slope of the delta plot for the fastest reactions ($r = .17$, $p = .42$).

It is interesting to note that different delta plot patterns were obtained for the picture–word interference task and the Stroop task. Whereas the delta plots for picture–word interference suggest that selective inhibition was applied in this task, those for the Stroop task suggest that inhibition was not applied in this task. One might wonder whether this difference across tasks could be related to the fact that the delta-plot analyses were based on quintiles for the two picture-naming tasks and tertiles for the Stroop task. However, when tertiles were used for all tasks, the pattern remained unchanged. For the two picture-naming tasks, the slopes of the slowest delta segments were significantly correlated with the magnitude of the interference effect: picture–word interference task ($r = .65$, $p < .001$); semantic blocking task ($r = .35$, $p < .05$). There were no significant correlations between the slope of the slowest delta segment of the Stroop task and the corresponding slopes in any of the other naming tasks: correlation with the slopes in the picture–word interference task ($r = .27$, $p = .10$); correlation with the slopes in the semantic blocking task ($r = -.22$, $p = .15$).

The differences in the results seen for the picture-naming and Stroop tasks is remarkable since Stroop is often viewed as being

[1] We report correlation coefficients with the associated significance levels ($p < .01$ or $p < .001$) without correcting for multiple comparisons. However, with one exception, which concerns the slopes of fastest delta segments in picture–word interference in Study 2, all correlations we describe as being significant are significant at $p < .05$ when Bonferroni correction is applied with the appropriate family size (i.e., family size of two tests for the correlations of effect sizes with the fastest and slowest slopes of the delta plot, family size of three tests for the effect sizes in the three naming tasks, and family size of four tests for the correlations of the RTs in the control conditions of the naming tasks and the stop-signal RT).

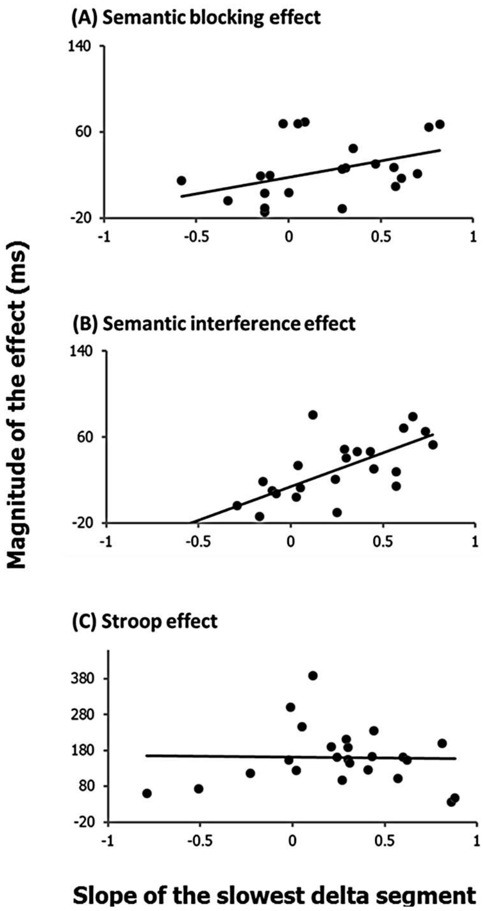

Figure 2. Scatter plots of the relationship between the magnitude of the interference effects and the slopes of the slowest delta segments in (A) the semantic blocking task, (B) the picture–word interference task, and (C) the Stroop task.

closely related to the picture–word interference task and as a prototypical interference task (e.g., Glaser & Düngelhoff, 1984; Glaser & Glaser, 1982; Roelofs, 2003; Schnur & Martin, 2012). But as described above, whereas some earlier studies (e.g., Bub et al., 2006) found evidence for the involvement of selective inhibition in the Stroop task, others did not (e.g., Soutschek et al., 2013). The latter studies and the present findings suggest that successful Stroop task performance might depend on other control abilities than selective inhibition (see Roelofs, 2003). Note that in the present Stroop task, there were fewer trials than in the picture-naming tasks, so tertiles rather than quintiles were used to compute the delta plots. Consequently, power might have been lower in the Stroop task than the picture-naming tasks. We further discuss this issue in the introduction of Study 2.

As we mentioned before, if selective inhibition is applied to resolve lexical competition, the interference effect size will be attenuated and sometimes reverse polarity (i.e., become facilitation rather than interference) for slow responses. To examine this prediction, we derived scatter plots for the relationship between the magnitude of the interference effect and the delta value of the last quantile for each task. As shown by Figure 3, about one third of the participants had zero effects or facilitation effects for the last quantile for the two picture-naming tasks, but none of them had such facilitation effect in the Stroop task. This is in line with our finding of a correlation between the size of the interference effect and the slope of the slowest delta segment in the semantic blocking and picture–word interference tasks but not in the Stroop task.

Stop-signal task. For the stop-signal task, the error rate on go-trials was 2.13%, and the estimated SSRT was 283 ms. These values are similar to those found in previous studies (e.g., Logan, Schachar, & Tannock, 1997; Shao et al., 2012).

Correlations among measures. In addition to analyzing the participants' performance in each task, we assessed the consistency of their performance across tasks. The results showed no correlations between the naming RTs in the control conditions of the three naming tasks (i.e., heterogeneous blocking, unrelated picture–word interference, and neutral Stroop) and the stop-signal task (rs $< .12$). But we did find strong correlations between the RTs in the control conditions of the semantic blocking task and picture–word interference task ($r = .62$, $p < .001$) and between the picture–word interference task and the Stroop task ($r = .58$, $p < .001$). This suggests that there was consistency in the participants' naming speed across tasks.

We did not replicate our earlier finding of a correlation between stop-signal RT and overall naming speed (Shao et al., 2012, 2013),

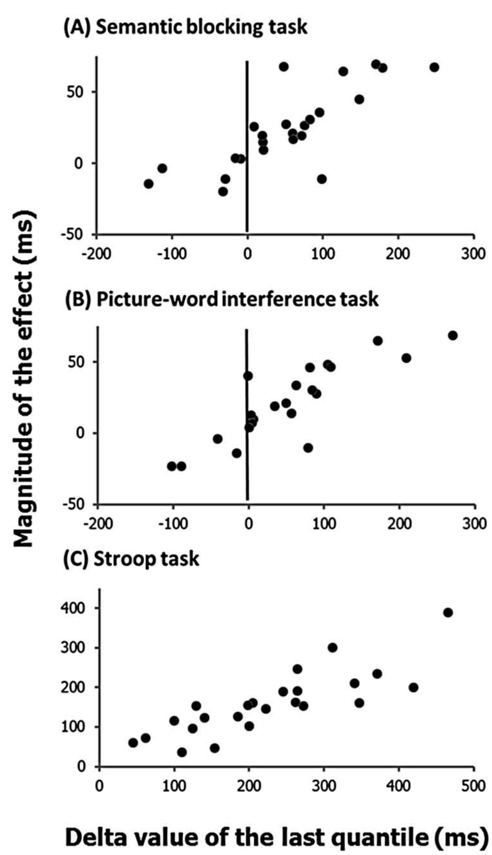

Figure 3. Scatter plots of the relationship between the magnitude of the interference effects and the delta values of the last quantile in (A) the semantic blocking task, (B) the picture–word interference task, and (C) the Stroop task.

suggesting that the overall naming speed was less affected by nonselective inhibition in the present than in the earlier studies. It is important to note that we did replicate the finding that the stop-signal RT was unrelated to the slope of the slowest delta segment and the magnitude of the interference effect in all three naming tasks (*p*s $>$ .10).

Finally, we examined the relationship among the magnitudes of the interference effects in the three naming tasks. As expected, the results showed a high correlation between the size of the participants' semantic interference effect and the size of their semantic blocking effect (r = .70, p < .001). The correlations of both effects to the Stroop effect were much lower and not significant (*r*s < .24, *p*s > .26). Furthermore, the slopes of the slowest delta segments in the two picture-naming tasks were likewise highly correlated (r = .97, p < .001); but neither of them correlated with the slopes in the Stroop task (*r*s < .32, *p*s > .12). This suggests that the semantic interference effects of the two picture-naming tasks were closely related to the participants' selective inhibition ability, whereas the Stroop effect was not.

Study 2

In Study 1, we used the same materials in the semantic blocking and picture–word interference tasks. This allowed us to compare performance on these tasks without contamination by differences in materials. However the correlations between tasks might be inflated through item-specific influences. The absence of correlations between the picture-naming tasks and the Stroop task might be due to the fact that different materials were used in the Stroop task. In Study 2, we used different materials for the two picture-naming tasks to examine whether the correlations observed in Study 1 were caused by the use of the same materials.

For the Stroop task, we had found in Study 1 that the slope of the slowest delta segment was unrelated to the mean magnitude of the Stroop effect. However, in calculating delta plots, we divided RTs into tertiles instead of quintiles because of the relatively small number of trials in Stroop task. In Study 2, we increased the number of trials in Stroop task from 72 to 180 so that quintiles could be used in all three naming tasks.

Method

Participants. The study was carried out with 28 native Dutch speakers (3 men; age: M = 20.28 years, range = 18 to 25 years). They were recruited from the participant pool of the Max Planck Institute for Psycholinguistics in Nijmegen, the Netherlands. All participants had normal or corrected-to-normal vision and normal hearing. They were paid for their participation. Participants were tested individually and the order of tasks was the same as in Study 1.

Picture–word interference task and stop-signal task.

Materials, design, and procedure. The materials, design and procedure of the picture-word interference task and stop-signal task were the same as in Study 1.

Semantic blocking task.

Materials, design, and procedure. A different set of materials was used, which consisted of 16 line-drawings of common objects adopted from the Snodgrass and Vanderwart (1980) corpus, drawn from four categories (clothing, transportation, weapons, and kitchenware, listed in the Appendix). All picture names were monosyllabic or disyllabic. The average log-word-form frequency in the SUBTLEX-NL database was 1.46/million (SD = 0.52), and the average age of acquisition was 5.3 years (SD = 1.26 years; Ghyselinck et al., 2000). The design and procedure were the same as in Study 1.

Stroop task.

Materials, design, and procedure. The materials, design, and procedure were the same as Study 1, except that each color was presented 20 times in each condition. This led to a total of 60 trials in each condition.

Results and Discussion

The data obtained from four participants were excluded due to high error rates in the stop-signal task (mean error rate for the bad participants: 14.9%) and technical problems during recording. Table 2 summarizes the error rates and RTs for the remaining participants in all tasks.

Semantic blocking task. Log-transformed naming RTs of the semantic blocking task were submitted to mixed-effects model analysis. Fixed effects were blocking context, trial number, and task order, and random effects included random intercept for participants and items, and random slope of blocking context for participants and items. The results showed a significant main effect of blocking context (t = 3.4), with the average naming RT being longer (by 30 ms) in the homogeneous than in the heterogeneous condition. There was also a main effect of trial number (t = −5.38) with the naming RTs decreasing across trials. In a second analysis we replaced trial number by cycle number and reran the mixed-effects model analysis. The main effect of blocking context was confirmed and a main effect of cycle was found (t = −9.90). Additionally, there was a significant interaction between blocking context and cycle (t = 4.42; see Figure 4). No main effect of task order was found (t < 0.17). Error rates were analyzed using mixed logit models. There was no main effect of blocking context, trial number/cycle number, or task order (*z*s < 1.32, *p*s > .19).

Because there was no blocking effect in the first cycle (the RTs in the homogeneous condition were slightly shorter than those in the heterogeneous condition), RTs from cycle 1 were excluded from the following analysis. Then delta plots were computed and

Table 2
Mean Reaction Time (in Milliseconds) and Error Rate per Condition for the Semantic Blocking (SB) Task, the Picture–Word Interference (PWI) Task, the Stroop Task, and Go-Trials of the Stop-Signal Task for Study 2

		Reaction time		Error rate (%)	
Task	Condition	*M*	*SD*	*M*	*SD*
SB	Homogeneous	660	82	2.13	.66
	Heterogeneous	630	74	1.99	1.43
PWI	Related	786	131	.57	.01
	Unrelated	752	121	.26	.46
Stroop	Incongruent	718	126	0.23	0.49
	Congruent	609	92	0.07	0.23
	Neutral	581	81	0.03	0.14
Stop-signal	Go trials	598	155	3.11	4.25

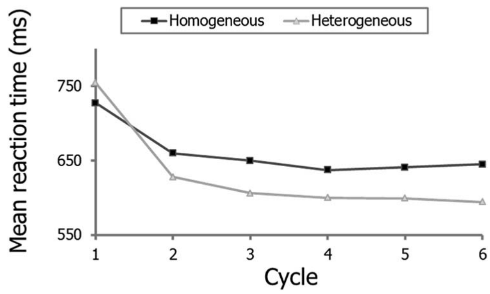

Figure 4. Mean naming reation time (RT; in milliseconds) in the semantic blocking task over cycles, broken down by blocking context.

we assessed the correlation between the slopes of the slowest delta segment and the magnitude of the mean interference effect for each participant. We found a significant correlation ($r = .62$, $p < .01$). Figure 5A show the corresponding scatterplot. We found no correlation between the slopes of the fastest delta segment and the magnitude of the mean interference effect for each participant ($r = -.06$).

Picture–word interference task. As for the semantic blocking task, log-transformed naming RTs of the picture–word interference task were submitted to mixed-effects model analysis. Fixed effects were distractor condition, trial number, and task order, and random effects included random intercept for participants and items, and random slope of distractor condition for participants and items. There was a significant main effect of distractor condition ($t = 3.74$), with the average RT being slower by 34 ms in the semantically related than in the unrelated condition. There was also a significant main effect of trial number ($t = 3.06$), suggesting that naming RTs decreased across trials. In the mixed logit model analysis of the accuracy, there was a significant main effect of distractor condition ($z = -2.09$, $p < .05$), with more errors occurring in the semantically related than in the unrelated condition. No other main effects or interactions were found (ps $> .10$).

As for the semantic blocking task, we assessed the correlation between the slopes of the slowest delta segment and the magnitude of the mean interference effect for each participant. We found a significant correlation ($r = .59$, $p < .01$). Figure 5B shows the corresponding scatter plot. We then assessed the correlation between the slopes of the fastest delta segment and the magnitude of the mean interference effect for each participant. In contrast to the result found for the semantic blocking task, this correlation was significant as well ($r = .42$, $p = .04$; though not after Bonferroni-correction for two comparisons).

Stroop task. Log-transformed naming RTs in Stroop task were submitted to the mixed-effects model analysis. The fixed effects were condition (congruent, neutral, and incongruent) and trial number. The random effects were random intercept for participants and random slope of condition for participants. Naming RTs in the neutral condition were significantly shorter than RTs in the congruent condition ($t = 4.83$), and RTs in the incongruent condition ($t = 20.73$). In addition, RTs became shorter across trials ($t = 2.31$). Error rates were submitted to mixed logit model analysis. Error rates did not significantly differ among neutral, congruent and incongruent condition (ps $> .12$).

As for the other two naming tasks, delta plots were computed for the Stroop task. There was no correlation between the size of the Stroop interference effect and the slope of the delta plot for the slowest reactions ($r = -.10$, $p = .64$). Figure 5C shows the corresponding scatter plot. There was also no correlation between the size of the Stroop interference effect and the slope of the delta plot for the fastest reactions ($r = -.23$, $p = .28$).

Figure 6 shows the scatter plots for the relationship between the magnitude of interference effect and the delta value of the last quintile for each task. As in Study 1, we found that some participants had a negative effect in the semantic blocking and picture–word interference tasks, but not in the Stroop task.

Stop-signal task. For the stop-signal task, the estimated SSRT was 265 ms ($SD = 37$ ms). This value is similar to that found in earlier research and in Study 1 above (e.g., Logan et al., 1997; Shao et al., 2012).

Correlations among measures. In addition to analyzing the participants' performance in each task, we assessed the consistency of their performance across naming tasks. Also, we assessed the correlation between the naming RTs in the control conditions of the three naming tasks (i.e., heterogeneous blocking, unrelated picture–word interference, and neutral Stroop) and the stop-signal task. The correlations among the naming latencies of the three

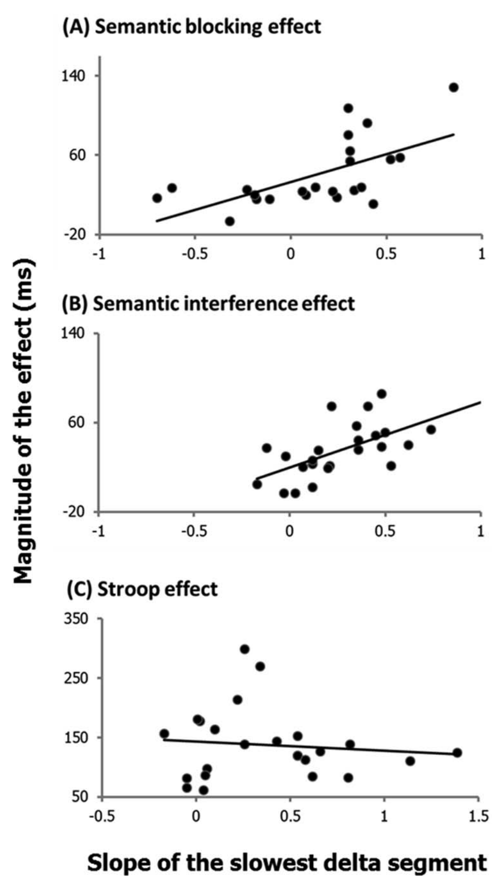

Figure 5. Scatter plots of the relationship between the magnitude of the interference effects and the slopes of the slowest delta segments in (A) the semantic blocking task, (B) the picture–word interference task, and (C) the Stroop task.

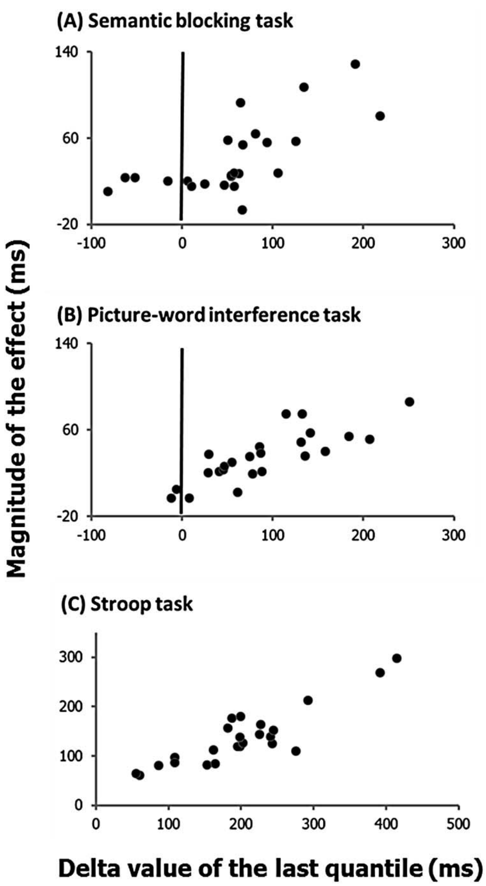

Figure 6. Scatter plots of the relationship between the magnitude of the interference effects and the delta values of the last quantile in (A) the semantic blocking task, (B) the picture–word interference task, and (C) the Stroop task.

naming tasks were high (rs > .73, ps < .001). As in Study 1, the stop-signal RT did not correlate with the RTs of the three naming tasks (rs < .19, ps > .38).

Then we computed the correlations between the magnitudes of the interference effects in the three naming tasks, as well as the correlations between the mean interference effects and the slopes of the delta plots for the slowest naming RTs. Similar to the results of Study 1, we found significant correlations between the magnitudes of the interference effects and the slopes within and across semantic blocking and picture–word interference tasks (rs > .49, ps < .01), but not for the Stroop task (rs < .18, ps > .24). However, different from Study 1, we now found a correlation between the interference effect in the picture–word interference task and the Stroop task (r = .55, p < .01). Again there was no correlation between SSRT and the slopes (ps > .08).

As in Study 1, we obtained the typical interference effects for the semantic blocking, picture–word interference, and Stroop tasks. We also found that naming RTs across the three naming tasks correlated with each other, indicating that participants' naming speed was relatively consistent across tasks. More importantly, we found a correlation between the magnitude of the interference effect and the slope of the slowest delta segment for the semantic blocking task and the picture–word interference task, even though now different pictures were used in the two tasks. We again found that the Stroop effect was uncorrelated with the slope of the slowest delta segment in the Stroop task, suggesting that selective inhibition was not engaged in the Stroop task. Finally, the stop-signal RT was unrelated to the magnitude of the interference effect and the slope of the slowest delta segment.

General Discussion

In two studies, we investigated whether explicit distractors are necessary and sufficient for evoking selective inhibition in naming. To this end, we used three naming tasks that differed in the use of explicit distractors: semantic blocking, picture–word interference, and color–word Stroop. Distractors were physically present on each trial in the picture–word interference and color–word Stroop tasks but not in the semantic blocking task. Following previous research, delta-plot analyses were conducted to quantify the size of the interference effects as a function of RT. Selective inhibition was operationalized as the decrease in the size of the interference effect as function of naming RT.

In both studies, we obtained the typical finding that naming latencies were longer in the interference condition (i.e., the homogeneous, semantically related, and incongruent conditions of the semantic blocking, picture–word interference, and Stroop task, respectively) than in the control conditions (the heterogeneous, unrelated and neutral condition). Comparing the two picture-naming tasks, we found that the participants' naming latencies in the control conditions (i.e., heterogeneous blocking, unrelated picture–word interference) were highly correlated both when using the same materials (Study 1) and when using different materials (Study 2). This shows that the speakers varied in their average naming latencies and that their performance was consistent across the tasks. This is in line with earlier results demonstrating high correlations between the naming latencies for object and action pictures (e.g., Shao et al., 2012). In other words, there appear to be faster and slower namers (cf. Laganaro, Valente, & Perret, 2012).

In two earlier studies (Shao et al., 2012, 2013), we found that naming RTs correlated with the SSRT, suggesting the involvement of nonselective inhibition in naming. We did not replicate this finding here. This might be related to differences in the materials used in the current study and our previous studies. In Shao et al. (2012) we used a large set of object and action pictures (262 in total) without repetition, and in Shao et al. (2013) we used a relatively large set of stimuli (56 objects) with one repetition. By contrast, in the present study we used a small set of stimuli (16 objects in the two picture-naming tasks and three colors in the Stroop task) with multiple repetitions in each naming task. The correlation between naming speed and SSRT may be reduced by increasing familiarity with the task or the stimuli (see Dimoska & Johnstone, 2008, for a related suggestion). This is consistent with the idea that nonselective inhibition is used to inhibit irrelevant information (Shao et al., 2012): When participants are more familiar with the task and stimuli, irrelevant information is less likely to be activated.

As in our earlier study, we found that the size of the interference effects was not correlated with the participants' performance in the stop-signal task. This suggests that nonselective inhibition is not involved to reduced response competition (cf. Shao et al., 2013).

However, since the SSRT did not correlate with the overall naming latencies or the latencies in the control conditions of the naming tasks, the absence of correlations with the interference effects should be seen as merely suggestive.

Returning to the comparison of the two picture-naming tasks, we found that the participants not only performed very similarly in terms of their latencies in the control conditions, but also experienced similar amounts of interference; that is, the magnitudes of the mean interference effects were highly correlated. The slopes of the slowest delta segments of the two picture-naming tasks were likewise highly correlated. Thus, participants who had relatively large or small semantic blocking effects also had relatively large or small semantic interference effects in the picture–word interference task. This implies that the speakers' ability to cope with semantic interference was consistent across these two naming tasks and suggests that the underlying mechanisms may be similar.

Turning to the role of selective inhibition in naming, we found strong evidence for the involvement of selective inhibition in the picture–word interference task: The participants with larger interference effects showed steeper slopes for the slowest segment of the delta plot than the participants with smaller interference effects. This replicates an earlier finding (Shao et al., 2013). It is important to note that a similar pattern was seen in the semantic blocking task. Again, there was a significant correlation between the size of the participants' interference effects and the slope of the slowest segment in the delta plot. Moreover, the correlation between the participants' slopes of the slowest delta segments in the two tasks was high (i.e., $r = .97$ in Study 1; $r = .49$ in Study 2). This pattern suggests that selective inhibition is a trait-like ability, manifesting similarly in the two naming tasks.

We acknowledge that no independent behavioral measure of selective inhibition (e.g., Simon task) was included in the present two studies. Our conclusions are based on the assumption that selective inhibition is reflected in the slope of slowest delta segment, which is supported by the literature (e.g., Burle et al., 2002; Forstmann et al., 2008a, 2008b; Proctor et al., 2011; Ridderinkhof et al., 2005; Van den Wildenberg et al., 2010; Wylie et al., 2009). To corroborate this assumption, we assessed the correlation between the mean interference effect in all naming tasks and the slope of the first (fastest) delta segment for Study 1 and 2. With one exception (the picture–word interference experiment of Study 2), the correlations were not present for the first delta segments. Thus, the correlational results are in line with our expectations: We consistently observe strong correlations between the magnitudes of the interference effects and the slopes of the slowest delta segments, but only once see a correlation between the magnitudes of the interference effects and slopes of the fastest delta segments. This pattern fits well with the assumption that selective inhibition takes time to be employed and therefore mostly affects relatively slow responses.

The results for the semantic blocking task imply that the presence of a single highly salient distractor (as in picture–word interference) is not a necessary condition for observing the recruitment of selective inhibition in a naming task. Instead, selective inhibition is also recruited when several responses are highly coactivated because they are part of a small response set or have recently been produced (as in semantic blocking). Though the current study is, to our knowledge, the first to demonstrate directly that selective inhibition can be involved in the absence of overt distractor stimuli that induce different degrees of conflict, the result fits in well with the observation of Biegler, Crowther, and Martin (2008) that patients with a deficit in inhibiting verbal representations showed a greatly exaggerated semantic blocking effect.

Moreover, our results suggest that the presence of a salient visual distractor is not sufficient for triggering inhibition either. We found no evidence for the engagement of selective inhibition in the Stroop task, even though a salient distractor is visually present in this task. For the Stroop task, there was no correlation between the size of the participants' mean interference effects and the slopes of their slowest delta segments in the delta plots, and there was no correlation of these slopes with the corresponding slopes in the picture-naming tasks.

The absence of evidence for the engagement of selective inhibition in the Stroop task is remarkable since this task is often viewed as being closely related to the picture–word interference task and as a prototypical interference task (e.g., Glaser & Düngelhoff, 1984; Glaser & Glaser, 1982; Roelofs, 2003; Schnur & Martin, 2012). Moreover, it is often assumed that the Stroop task measures inhibition ability (e.g., Miyake et al., 2000; Nigg, 2000). However, results similar to ours were obtained by Lamers et al. (2010) and Pratte et al. (2010). Bub et al. (2006) obtained evidence suggesting that younger children (7–9 years) engage in stronger inhibition than older children (9–11 years) in a vocal Stroop task. Perhaps participants do not need to strongly suppress word-reading when they grow older, as is suggested by our results for adult participants. Notably, the size of the Stroop effect is much larger than the semantic interference effects. This may be due to the fact that the semantic effect in picture–word interference concerns a difference in RT between two distractor-word conditions, a semantically related and unrelated one, whereas the Stroop interference effect concerns a difference in RT between a word condition (i.e., incongruent color words) and a nonword string of characters (e.g., a series of Xs or hash marks). Previous research (e.g., Glaser & Düngelhoff, 1984) has shown that in picture–word interference, the difference in RT between trials with incongruent distractor words (i.e., semantically related words) and nonword strings of characters (e.g., a series of Xs or hash marks) is also much larger than the difference between trials with semantically related and unrelated words (i.e., the semantic interference effect). Also, in the Stroop task, unlike the typical administration of the picture–word interference task, there are congruent trials where the written word matches the color. Previous studies have shown a congruency proportion effect, with smaller Stroop effects with a lower proportion of congruent trials (e.g., Logan, 1980). This congruency proportion effect has been argued to derive from subjects' greater engagement of top-down control processes to suppress word reading when the congruency proportion is small (e.g., West, 1999) and also from item-specific learning of the proportion of congruent word trials (Jacoby, Lindsay, & Hessels, 2003). Thus, variation in selective inhibition for the Stroop task may derive from variation in the proportion of congruent trials across studies. However, regardless of exactly why the engagement of selective inhibition in the Stroop task is variable, apparently more so than in the picture–word interference task, on the basis of our results we can conclude that selective inhibition is not necessarily triggered by visually present distractor (as present in the Stroop task).

One may wonder what the implications of our findings are for models of word production such as WEAVER++ (Levelt et al., 1999; Roelofs, 2003, 2008, 2014). An important distinction is between attentional top-down inhibition (which is what we studied) and automatic lateral inhibition between nodes within word planning levels. WEAVER++ has no such lateral inhibitory links between nodes but may implement top-down inhibition. The model makes a distinction between declarative (i.e., associative memory) and procedural (i.e., condition-action rule) aspects of spoken word planning (e.g., Roelofs, 2003, 2008, 2014). The associative network contains information about words, including their concepts, lemmas, morphemes, phonemes, and motor programs. The network is accessed by spreading activation while condition-action rules select target nodes among activated competing nodes in line with the task demands specified in working memory. In WEAVER++, selection of a target lemma requires that the difference in activation levels between the target and competitors exceeds a critical difference. The condition-action rules mediate top-down influences by selectively enhancing the activation of target nodes. Similarly, condition-action rules may mediate top-down inhibitory influences by selectively lowering the activation of competitors (although this has not been implemented in the model yet). If selective inhibition takes time to be applied, the effect of selective inhibition will be more pronounced for trials with longer RTs, as empirically observed.

Finally, one may ask what the present results imply for the origin and functional locus of the interference effects in the picture–word interference and semantic blocking paradigms. We did not directly examine this question in the present study. According to the lexical selection-by-competition account, both the semantic interference effect and the semantic blocking effect arise at the level of lexical selection, where a specific lemma is chosen that matches the intended concept. The semantic effect is due to competition between target lemma and strong competitors. Selective inhibition may be applied to reduce the activation of the strong competitors. According to the response-exclusion account, the semantic interference effect from distractor words in picture naming arises at the level of the articulatory buffer. A written distractor word is assumed to activate its motor program, which will occupy the buffer and needs to be removed. It is stipulated that it take longer to remove the motor program of a semantically related distractor word than an unrelated one. Selective inhibition may help remove the motor program for the distractor word from the buffer. However, in the semantic blocking task, there are no distractor words that could activate their motor programs. Consequently, it is not clear how selective inhibition support response-selection in this paradigm. Thus, our evidence for a similar role of selective inhibition in the semantic blocking and picture–word interference tasks is more in line with the selection-by-competition than the response exclusion account.

Conclusions

A main goal of the present investigation was to determine whether selective inhibition would be involved in a task where speakers did not have to suppress a response to a single salient distractor, as is the case in the picture–word interference task. The results of the semantic blocking task clearly support this hypothesis. Thus, selective inhibition is invoked not only when speakers have to suppress their reactions to a single distractor, but also when strong competition arises between conceptual or lexical units for other reasons, for instance due to the prior experience in an experiment. The results of the semantic blocking task suggest that a single visually present distractor is not necessary for triggering inhibition, and the results of the Stroop task suggest that such a visually present distractor is also not sufficient for evoking inhibition.

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(*Appendix follows*)

Appendix

List of Target Names of Pictures Used in Semantic Blocking and Picture–Word Interference Tasks

Study	Items
1 and 2	ANIMALS: eend (duck), muis (mouse), slang (snake), vis (fish)
	FURNITURE: bed (bed), kast (wardrobe), lamp (lamp), stoel (chair)
	TOOLS: boor (drill), hark (rake), tang (pliers), zaag (saw)
	BODYPARTS: arm (arm), neus (nose), oor (ear), voet (foot)
2	CLOTHING: jas (jacket), hemd (singlet), rok (skirt), trui (sweater)
	TRANSPORTATION: auto (car), bus (bus), trein (train), fiets (bicycle)
	WEAPONS: dolk (dagger), zwaard (sword), kanon (cannon), pistool (gun)
	KITCHENWARE: kan (pitcher), beker (cup), bord (plate), glas (glass)

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Correction to Shao et al. (2015)

In the article "Selective Inhibition and Naming Performance in Semantic Blocking, Picture-Word Interference, and Color-Word Stroop Tasks," by Zeshu Shao, Ardi Roelofs, Randi C. Martin, and Antje S. Meyer (*Journal of Experimental Psychology: Learning, Memory, and Cognition*, Advance online publication. June 1, 2015. http://dx.doi.org/10.1037/a0039363), Antje S. Meyer should not be affiliated with Rice University. All versions of this article have been corrected.

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