Task Choice and Semantic Interference in Picture Naming

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Abstract

Evidence from dual-task performance indicates that speakers prefer not to select simultaneously responses in picture naming and another unrelated task, suggesting a response selection bottleneck in naming. In particular, when participants respond to tones with a manual response and name pictures with superimposed semantically related or unrelated distractor words, semantic interference in naming tends to be constant across stimulus onset asynchronies (SOAs) between the tone stimulus and the picture-word stimulus. In the present study, we examine whether semantic interference in picture naming depends on SOA in case of a task choice (naming the picture vs reading the word of a picture-word stimulus) based on tones. This situation requires concurrent processing of the tone stimulus and the picture-word stimulus, but not a manual response to the tones. On each trial, participants either named a picture or read aloud a word depending on the pitch of a tone, which was presented simultaneously with picture-word onset or 350 ms or 1000 ms before picture-word onset. Semantic interference was present with tone pre-exposure, but absent when tone and picture-word stimulus were presented simultaneously. Against the background of the available studies, these results support an account according to which speakers tend to avoid concurrent response selection, but can engage in other types of concurrent processing, such as task choices.

Key words: dual task; naming; picture-word interference; semantic interference; task choice

1. Introduction

Speaking is a highly exercised psychomotor skill and accessing words in memory forms an essential part of this skill (Levelt, 1989). Being such a well-practised activity, it feels as if speaking happens automatically. Yet, evidence has accumulated that certain linguistic processes required for speaking, such as lexical selection, cannot occur simultaneously with certain nonlinguistic processes (see for review Roelofs & Piai, 2011). Which types of nonlinguistic processes can or cannot happen in parallel with lexical selection in speaking is addressed in the present study. Below, we first introduce a paradigm often used to investigate lexical selection and outline our current understanding of how lexical response selection precludes other concurrent nonlinguistic processes. Next, we discuss evidence suggesting that speakers tend to avoid concurrent response selection but can engage in other types of concurrent processing, such as task choices. We then present two experiments explicitly testing whether lexical selection can occur simultaneously with making task choices.

1.1. Picture naming and dual-task procedures

An experimental paradigm particularly fruitful for investigating lexical access in word production is picture-word interference (e.g., Abdel Rahman & Melinger, 2009; Glaser, 1992; Roelofs, 2007, for reviews): Speakers name pictured objects while trying to ignore written distractor words superimposed onto the pictures. A central finding obtained with picture-word interference (PWI) is that response time (RT) is longer for picture naming when the word is from the same semantic category as the picture name (related condition, picture: goat, word: *horse*) relative to unrelated words (word: *pen*), called the semantic interference effect.

In the past few years, researchers have used the PWI paradigm in combination with a dual-task procedure, called the psychological refractory period (PRP) paradigm (Pashler, 1994), to investigate at which stage during word production the semantic interference effect arises (Dell'Acqua et al., 2007; Kleinman, 2013; Piai, Roelofs, & Schriefers, 2014; Schnur &

Martin, 2012). In a PRP experiment, participants respond quickly and accurately to two stimuli (S1 and S2) in the correct order (i.e., first to S1, then to S2) while the stimulus onset asynchrony (SOA) between S1 and S2 is varied to determine whether processes are delayed due to concurrent processing. To investigate the locus of semantic interference, researchers have employed a combination of a manual tone discrimination task (Task 1) and the PWI task (Task 2).

A prominent view in the literature maintains that, when tasks are performed concurrently, response selection constitutes a processing bottleneck. The response selection bottleneck implies that only one response can be selected at a time. The bottleneck is assumed to be structural (Pashler, 1994) or strategically imposed (Meyer & Kieras, 1997). The view of a response selection bottleneck holds that in a PRP experiment, a response for Task 2 (e.g., picture naming) can only be selected after the response for Task 1 (e.g., tone discrimination) has been selected and this waiting for response selection for task 1 creates *cognitive slack* (Pashler, 1994). With a long SOA between S1 and S2 (e.g., S1 preceding S2 by 1000 ms), the response-selection stages of Tasks 1 and 2 do not overlap. Under these conditions, Task 2 manipulations yield similar effects as in a situation with only Task 2 (e.g., manipulating distractor type in PWI yields the semantic interference effect in picture naming). With a short SOA (e.g., 0 or 100 ms) between S1 and S2, however, effects can be present of absent, providing evidence about the locus of the effect of Task 2 manipulations. According to the slack logic, the presence of an effect at short SOAs provides evidence that the effect emerges at response-selection or at post-selection stages. This is illustrated in Figure 1, which assumes a response-selection locus of semantic interference. By contrast, the absence of such an effect is taken as evidence that the effect emerges prior to response selection and is absorbed into slack.

In previous PRP studies examining the locus of the semantic interference effect in picture naming over a wide range of SOAs, two main patterns have been observed (for an overview, see Piai, Roelofs, & Schriefers, 2014). Some studies reported that the semantic interference effect is absent (or clearly reduced) at short SOAs, but present at long SOAs (Ayora et al., 2011; Dell'Acqua et al., 2007; Kleinman, 2013; van Maanen, van Rijn, & Taatgen, 2012). The underadditive effect of SOA and distractor type suggests a pre-selection locus of the semantic interference effect (Ayora et al., 2011; Dell'Acqua et al., 2007), or can be interpreted as evidence that response selection processes of Tasks 1 and 2 may overlap (Roelofs & Piai, 2011). Most commonly, however, it has been observed that the semantic interference effect is of similar magnitude at short and long SOAs, that is, additive effects of SOA and distractor type are obtained (Kleinman, 2013; Piai & Roelofs, 2013; Piai, Roelofs, & Roete, 2014; Piai, Roelofs, & Schriefers, 2014; Schnur & Martin, 2012; van Maanen et al., 2012). The additivity suggests that the semantic interference effect emerges during lexical response-selection or later stages, as shown in Figure 1. Thus, in the remainder of this article, we adopt the assumption that the locus of the semantic interference effect is at selection or post-selection stages (see for extensive discussion Piai, Roelofs, & Schriefers, 2014). Note that the aim of the present study is not to test this assumption, but rather to investigate whether the additivity of the semantic interference effect depends on the nature of the concurrent processes.

Piai, Roelofs, & Schriefers (2014) systematically manipulated various dimensions on which earlier PRP studies differed, including tasks, materials, stimulus types, and SOAs. Still, in all experiments, additive effects of SOA and distractor type on naming RTs were obtained. Piai et al. therefore concluded that "participants strongly prefer imposing a response-selection bottleneck (yielding the pervasive additive effects) rather than a post-selection bottleneck (yielding the less-pervasive underadditive effects)" (pp. 161-162).

Essential to the response-selection bottleneck account of additive effects in dual-task performance is that only one response can be selected at a time. Consequently, effects arising in response selection for Task 2, such as semantic interference in picture naming, will not be absorbed into slack created by response selection in Task 1. This account entails that when Task 1 creates slack but does not involve response selection, semantic interference in Task 2 may be absorbed into slack. Under these circumstances, underadditive effects of distractor type and SOA may be obtained. Elsewhere (Piai, Roelofs, & Schriefers, 2011), we argued that such a situation may occur when Task 1 involves a task choice without response selection, as illustrated in Figure 2.

1.2. Picture naming and a task-choice procedure

Following Janssen, Schirm, Mahon, and Caramazza (2008), Piai et al. (2011) used a task-choice paradigm (Besner & Care, 2003), requiring a choice between picture naming and word reading on each trial. The print colour of the word indicated whether participants had to name the picture or read the word aloud. Using another group of participants, Piai et al. (2011) also examined picture naming without a task choice. The same PWI stimuli were presented, but now the picture had to be named on all trials. We observed that the semantic interference effect was present in picture naming without a task choice but absent with a task choice. Mädebach, Oppermann, Hantsch, Curda, and Jescheniak (2011) observed exactly the same. Piai et al. (2011) accounted for these findings by assuming that in the task-choice condition, the response to the picture is selected concurrently with the processing of the cue (the colour of the written word) for the task choice. The task choice creates cognitive slack in that a response to the picture cannot be given before the task choice has been made. The cognitive slack may absorb the semantic interference, as illustrated in Figure 2. However, different from Mädebach et al. (2011) and Piai et al. (2011), Janssen et al. (2008) did observe semantic interference with a task choice, suggesting that the slack created by a task choice may not always be sufficient to fully absorb semantic interference, or that participants may sometimes prefer not to fully overlap task choice and response selection processes.

Furthermore, Piai et al. (2011) assumed that picture and word processes initially run in parallel and are then suspended until the task-decision process is finished. Word-form encoding (indicated as the post-selection stage in the figure) in both picture naming and reading aloud requires central processing resources (Reynolds & Besner, 2006; Roelofs, 2008), and so does the task-decision process (Paulitzki, Risko, O'Malley, Stolz, & Besner, 2009). Therefore, Piai et al. assumed that naming and reading processes are suspended before word-form encoding so that central resources can be allocated to the task-decision process. We come back to this issue in the General Discussion.

1.3. Dual task versus task choice

The account of Piai, Roelofs, and Schriefers (2011, 2014; Roelofs & Piai, 2011) assumes that participants strongly prefer not to overlap response selection in picture naming with response selection in an another task in PRP experiments (yielding additive effects). But participants do allow response selection in picture naming to overlap with a task choice (yielding underadditive effects). There are, however, several methodological differences between the task-choice studies and PRP studies in the literature on semantic interference in picture naming. Consequently, the account by Piai, Roelofs, and Schriefers (2011, 2014; Roelofs & Piai, 2011) of the task-choice and PRP findings remains speculative.

An important difference between the task-choice and PRP studies concerns the type of Task 1 stimuli, which consisted of tones in the PRP studies (i.e., Dell'Acqua et al., 2007; Ayora et al., 2011; van Maanen et al., 2012; Piai & Roelofs, 2013; Piai, Roelofs, & Roete, 2014, Piai, Roelofs, & Schriefers, 2014; Schnur & Martin, 2012) and colours in the task-choice studies (i.e., Janssen et al., 2008; Mädebach et al., 2011; Piai et al., 2011). Moreover, the presence or absence of task choices (and thus slack) in the experiments of Piai et al.

(2011) was manipulated between participants, whereas the presence of slack in the PRP experiments was manipulated by varying SOAs within participants. By contrast, Piai et al. (2011) did not have an SOA manipulation. In that study, the semantic interference effect was absent when the task cue (print colour of the word) was presented at the same time as the picture-word stimulus, whereas the effect was present for another group of participants who did not have to make a task choice. Thus, there is no direct evidence for slack in the study of Piai et al. (2011). To demonstrate that the task-choice process is creating slack that may absorb the semantic interference effect, an SOA manipulation is needed showing that the semantic interference effect is absent when the task choice has to be made at the same time as the PWI stimuli are presented (SOA = 0 ms) but not when participants make the choice beforehand (SOAs with pre-exposure of the task cue). We refer to Pasher (1994) for an extensive discussion of the importance of an SOA manipulation in applying the slack logic.

To summarise, to account for the PRP findings of Piai, Roelofs, and Schriefers (2014), Piai and Roelofs (2013), and Piai, Roelofs, and Roete (2014), among others, we assume a (strategic) response-selection bottleneck. Thus, if there are two responses to be made on each trial, as in PRP experiments, then the response selection bottleneck is present and will affect performance. As a consequence, the semantic interference effect should be additive with the effect of SOA, as is typically observed (e.g., Piai, Roelofs, & Schriefers, 2014; Piai & Roelofs, 2013; Piai, Roelofs, & Roete, 2014; Schnur & Martin, 2012). However, if there is only one response to be made on each trial, as in task-choice experiments, then the response selection bottleneck is not present and will not affect performance. As a consequence, the semantic interference effect should be underadditive with the effect of SOA. In line with this latter prediction, Piai, Roelofs, and Schriefers (2011) and Mädebach et al. (2011) observed that the semantic interference effect was absent when a task choice had to be made, but the effect was fully present without task choices. However, none of the studies in the literature has explicitly tested the prediction that in task choice experiments, the semantic interference effect should be underadditive with the effect of SOA. Thus, direct support for the account of Piai et al. (2011, 2014) is lacking. The aim of the present task-choice experiments was to test this prediction of underadditive semantic and SOA effects.

1.4. The Present Study

We report two experiments that tested the account of Piai, Roelofs, and Schriefers (2011, 2014; Roelofs & Piai, 2011). This account states that the semantic interference effect in picture naming may diminish or disappear in case of a concurrent task choice (based on colours or on tones), requiring concurrent processing but no selection of a response to the tones. In particular, we examined whether the semantic interference effect diminishes or disappears if participants have to make a task choice while selecting the picture name (SOA = 0 ms) but is present as a full-blown effect when the task cue is preexposed (i.e., reducing or eliminating slack). Importantly, to be able to apply the slack logic and compare the results with those of Piai, Roelofs, and Schriefers (2014) and others, the design of the present experiments mimicked as much as possible that of the standard PRP experiments in the literature, but without requiring a response to S1.

Our participants decided between picture naming and word reading depending on a tone (rather than on colours). The use of tones is similar to the standard PRP experiments in the literature (Ayora et al., 2011; Dell'Acqua et al., 2007; Kleinman, 2013; Piai & Roelofs, 2013; Piai, Roelofs, & Roete, 2014; Piai, Roelofs, & Schriefers, 2014; Schnur & Martin, 2012; van Maanen et al., 2012) but different from the task-choice experiments in the literature (Janssen et al., 2008; Mädebach et al., 2011; Piai et al., 2011). In addition, the SOA between tone and picture-word stimuli was manipulated within participants.

In Experiment 1, the tone was presented either simultaneously with the picture-word stimulus (0-ms SOA) or 1000 ms before it. In the latter case, participants could make their task choice before having to perform the picture-word task. In Experiment 2, SOAs of 0 ms and 350 ms (tone pre-exposure) were used. If the slack account proposed by Piai et al. (2011) is correct, then at the 0-ms SOA, no semantic interference effect should be observed as it is absorbed into slack created by the task choice. Furthermore, according to their time estimates, 350 ms should be enough for the task-choice process to be finished, so little or no absorption of the semantic interference should occur at the 350-ms SOA. This means that for both SOAs of 350 and 1000 ms, semantic interference should be observed in picture naming with similar magnitude for the two SOAs. Finally, given that semantic interference is absent in word reading in picture-word interference (e.g., Glaser & Düngelhoff, 1984; Glaser & Glaser, 1989; Roelofs, 1992, 2003), no semantic interference effect should be obtained for word reading at any SOA.

2. Experiment 1

In the first experiment, we tested the prediction derived from Piai, Roelofs, and Schriefers (2011, 2014) that the absence of response selection but presence of slack in a task-choice situation should yield semantic interference at a long SOA and no (or a reduced) semantic interference effect at a short SOA. Following the PRP experiments of Piai, Roelofs, and Schriefers (2014), we used SOAs of 0 and 1000 ms, and tones as task cues.

2.1. Method

The experiment was approved by the Ethics Committee for Behavioural Research of the Social Sciences Faculty at Radboud University Nijmegen.

2.1.1. Participants

Twenty native speakers of Dutch (5 male) participated. All reported normal or corrected-to-normal vision, no history of reading disorders and no hearing problems.

2.1.2. Materials and design

Picture stimuli consisted of 32 black-and-white line drawings of objects, scaled to approximately 3.5 cm x 3.5 cm (the same materials as used by Piai et al., 2011). The 32 pictures came from eight semantic categories with four exemplars in each category (e.g., four pictures of animals, four pictures of body parts, etc.). Four additional pictures were used as practice items, none of which belonged to the experimental categories. We manipulated distractor type (related or unrelated), yielding 64 picture-word pairs. In the related condition, each target picture was combined with a word from the same semantic category. The unrelated condition was formed by re-pairing the pictures with different words from other categories. The distractor words were taken from the set of picture names and, thus, were members of the response set. Participants had to perform either picture naming or word reading, depending on the pitch of a tone. Two pure tones of 200 ms duration were used: 1000 Hz (low tone) and 1100 Hz (high tone). Whether the picture-naming task was determined by the low or high tone was counterbalanced across participants. The SOA values used were 0 ms and 1000 ms (tone pre-exposure). Trials were blocked by SOA and the order of SOAs was counterbalanced across participants. Each picture-word pair appeared twice with each tone and twice with each SOA, yielding 256 trials in total (64 picture-word pairs times 2 tones times 2 SOAs). The second presentation of a given pair only followed after the first presentation of all pairs. Trials were randomised with one unique list per participant using Mix (van Casteren & Davis, 2006).

2.1.3. Procedure

Stimulus presentation and response recording were controlled by Presentation Software (Neurobehavioral Systems). Vocal responses were measured with a voice key and the tones were presented via closed headphones. Before the experiment started, participants were familiarised with the pictures and their names using a booklet. Each SOA block started with four practice trials.

For the 0-ms SOA, each trial began with the picture-word stimulus and the tone presented simultaneously. For 1000-ms SOAs, the tone was presented and, after a delay of 1000 ms, the picture-word stimulus followed. The picture remained on the screen for 500 ms, followed by a black screen for 2 s. Then, the next trial started. The registration of the vocal responses started as soon as the picture-word stimulus was displayed and lasted 2.5 s.

2.1.4. Analysis

After each trial, participants' vocal responses were evaluated. Trials with voice-key errors were discarded. Trials with disfluencies or incorrect responses were coded as errors, analysed with logistic regression, and excluded from the analyses of the RTs. RTs were analysed with repeated measures analysis of variance, with distractor type (related vs. unrelated), SOA (0 vs. 1000 ms), and task (picture naming vs. word reading) as within-participants and within-items variables. Planned contrasts for the semantic interference effect were analysed with paired *t*-tests. Additionally, for the semantic interference effect, 95% confidence intervals (CI) are reported on the paired mean difference (related vs. unrelated), as well as Cohen's *d* as a measure of effect size.

2.2. Results

Table 1 shows the error percentages for picture naming and word reading as a function of SOA and distractor type. Error rates were similar across conditions in the logistic regression models, *p*s > .108.

Figure 3 (left panels) shows the normalised mean RTs for picture naming and word reading as a function of SOA and distractor type as well as 95% confidence intervals calculated with the Cousineau-Morey approach (Morey, 2008). RTs were overall longer in the related than in the unrelated condition, $F_1(1,19) = 7.02$, $MSE = 954$, $p = .016$, $F_2(1,31) = 5.16$, $MSE = 4443$, $p = .030$. Also, RTs were longer at the 0-ms than at the 1000-ms SOA, $F_1(1,19) = 207.05$, $MSE = 15053$, $p < .001$, $F_2(1,31) = 2882.30$, $MSE = 3260$, $p < .001$. Moreover, RTs were longer for picture naming than for word reading, $F_1(1,19) = 153.08$, $MSE = 8442$, $p < .001$, $F_2(1,31) = 265.53$, $MSE = 16005$, $p < .001$. The presence of a semantic interference effect depended on whether the task was picture naming or word reading, as indicated by the interaction between distractor type and task, $F_1(1,19) = 19.92$, $MSE = 570$, $p < .001$, $F_2(1,31) = 5.43$, $MSE = 6368$, $p = .026$. SOA and task also interacted, $F_1(1,19) = 13.16$, $MSE = 4100$, $p < .001$, $F_2(1,31) = 45.88$, $MSE = 3696$, $p < .001$, whereas distractor type and SOA did not interact, $F_1(1,19) = 1.27$, $MSE = 1252$, $p = .273$, $F_2(1,31) = 1.21$, $MSE = 3774$, $p = .279$. Importantly, the presence of a semantic interference effect was dependent on task and on SOA, as indicated by a significant three-way interaction of distractor type, SOA, and task, $F_1(1,19) = 6.36$, $MSE = 850$, $p = .021$, $F_2(1,31) = 7.83$, $MSE = 2622$, $p = .009$. Planned contrasts showed that, for the picture naming task, there was no effect of distractor type at the 0-ms SOA, $t_1(19) = 1.01$, $p = .327$, $t_2(31) < 1$, 95% *CI* [-13, 37], $d = .09$. However, the semantic interference effect at the 1000-ms SOA was significant, $t_1(19) = 5.05$, $p < .001$, $t_2(31) = 3.94$, $p < .001$, 95% *CI* [28, 68], $d = .42$. For the reading task, there was no effect of distractor type at any SOA, all *p*s > .100.

2.3. Discussion

In this experiment, participants decided which task to perform on a picture-word stimulus based on a tone task-cue. Task-choice processes could start either before picture-word onset (1000-ms SOA) or simultaneously with it (0-ms SOA).

At the 1000-ms SOA, the semantic interference effect was present, whereas at the 0-ms SOA, the effect was absent. These results replicate Mädebach et al. (2011) and Piai et al. (2011), but now with tones as task cues (i.e., the type of stimuli that are usually used as Task 1 stimuli in PRP studies on the locus of semantic interference). More importantly, the present results go beyond a replication of previous findings in that the presence or absence of semantic interference was now observed within the same participants as a function of when the task cue was presented, suggesting the involvement of slack. The finding of a clear semantic interference effect with task cue pre-exposure (1000-ms SOA) but not at 0-ms SOA suggests that slack was reduced or absent, lending support to our account that the absence or presence of slack determines whether semantic interference is detectable (slack absent) or not (slack present). Moreover, our results suggest that the absence of semantic interference at the 0-ms SOA is due to the absorption into slack created by the task choice in the absence of response selection.

3. Experiment 2

In Experiment 2, we decreased the value of the long SOA to further test the temporal aspects of the task-choice process. Thus, in Experiment 2, the SOAs of 0 ms and 350 ms (tone pre-exposure) were used. According to the account proposed by Piai et al. (2011), slack created by the task-choice process absorbs the semantic interference effect because this effect arises within 200-300 ms after picture-word onset. With a head-start of the task-choice process by 350 ms, still little or no absorption of the semantic interference effect should occur. Thus, we should find a pattern of results that is parallel to the one of Experiment 1, that is, no semantic interference at SOA 0 ms and a clear semantic interference effect at SOA 350 ms.

3.1. Method

The experiment was approved by the Ethics Committee for Behavioural Research of the Social Sciences Faculty at Radboud University Nijmegen.

3.1.1. Participants

Twenty native speakers of Dutch (3 male) participated. All reported normal or corrected-to-normal vision, no history of reading disorders and no hearing problems.

3.1.2. Materials, design, procedure and analysis

All aspects of this experiment were the same as for Experiment 1, but now the SOA values were 0 ms and 350 ms (tone pre-exposure). For the 350-ms SOA, the tone was presented and, after a delay of 350 ms, the picture-word stimulus followed. The same analyses were conducted as for Experiment 1.

3.2. Results

Table 1 shows the error percentages for picture naming and word reading as a function of SOA and distractor type. Error rates were similar across conditions, as revealed by the logistic regression models, *p*s > .219.

Figure 3 (right panels) shows the normalised mean RTs for picture naming and word reading as a function of SOA and distractor type as well as 95% confidence intervals calculated with the Cousineau-Morey approach (Morey, 2008). RTs were longer in the related than in the unrelated condition, $F_1(1,19) = 8.68$, $MSE = 1077$, $p = .008$, $F_2(1,31) = 5.66$, $MSE = 2353$, $p = .024$. RTs were also longer at the 0-ms than at the 350-ms SOA, $F_1(1,19) = 91.56$, $MSE = 17816$, $p < .001$, $F_2(1,31) = 1953.6$, $MSE = 1360$, $p < .001$. Moreover, RTs were longer for picture naming than for word reading, $F_1(1,19) = 168.49$, $MSE = 7663$, $p < .001$, $F_2(1,31) = 271.85$, $MSE = 7791$, $p < .001$. Distractor type and task did not interact, $F_1(1,19) = 1.95$, $MSE = 1711$, $p = .179$, $F_2(1,31) = 2.47$, $MSE = 2437$, $p = .126$. However, SOA and task interacted, $F_1(1,19) = 15.46$, $MSE = 1970$, $p < .001$, $F_2(1,31) = 34.35$, $MSE = 1418$, $p < .001$, whereas distractor type and SOA did not interact, $F_1(1,19) < 1$, $F_2(1,31) < 1$. The three-way interaction was only significant by participants, $F_1(1,19) = 5.72$, $MSE = 493$, $p = .027$, $F_2(1,31) = 1.47$, $MSE = 1532$, $p = .235$, indicating the possibility that that the presence of a semantic interference effect was dependent on task and SOA. Ideally, this interaction should only be followed up on in case both the by-participants and by-items analyses were significant. However, given the a-priori hypothesis of this interaction based on theoretical grounds and on the results of Experiment 1, we examined the effect of distractor type for each SOA separately. Planned contrasts revealed that, for the picture naming task, there was no effect of distractor type at the 0-ms SOA, $t_1(19) = 1.38$, $p = .184$, $t_2(31) = 1.42$, $p = .166$, 95%

CI [-8, 38], d = .14. However, the semantic interference effect at the 350-ms SOA was significant, $t_1(19) = 3.95$, $p < .001$, $t_2(31) = 2.36$, $p = .025$, 95% *CI* [16, 51], d = .42. For the reading task, there was no effect of distractor type at any SOA, all *p*s > .100.

3.3. Discussion

In this second experiment, task-choice processes started either 350 ms prior to picture-word presentation or simultaneously with it (0-ms SOA). Similar to Experiment 1, the semantic interference effect was descriptively clearly reduced and statistically absent at the 0-ms SOA, whereas it was present at the 350-ms SOA, replicating the findings of the 1000-ms SOA of Experiment 1. However, the three-way interaction on which this interpretation is based was only reliable in the by-participants analysis. Therefore, in order to increase statistical power for the preexposure SOAs, we conducted additional analyses on the combined data of Experiments 1 and 2.

4. Combined Analysis of Experiments 1 and 2

The analysis of the combined data of the two experiments served two purposes. First of all, we wanted to clarify the three-way interaction between task, SOA, and distractor type, which was reliable in Experiment 1 both by participants and by items, but only in the by-participants analysis in Experiment 2. To this end, we conducted an analysis of variance on the response latencies with experiment as a between-participants and within-items variable, in addition to the variables distractor type, task and SOA (short: 0 ms; long: 350 and 1000 ms). The relevant results, including these three latter factors, showed a reliable three-way interaction both by-participants and by-items, $F_1(1,38) = 11.94$, $MSE = 671$, $p = .001$, $F_2(1,31) = 5.62$, $MSE = 1828$, $p = .024$. Importantly, the factor experiment did not interact with these three factors (distractor type, task, and SOA), $F_1(1,38) < 1$, $F_2(1,31) = 1.15$, $MSE = 1023$, $p = .293$. These results provide further support for the findings of the analyses of the individual experiments that the presence of a semantic interference effect was dependent on task and on SOA.

Secondly, we wanted to assess whether there were any differences in the magnitude of the semantic interference effect in picture naming between experiments at the 0-ms SOA and, in particular, between the SOAs of 350 and 1000 ms. Therefore, an analysis of variance was conducted on the naming latencies only with experiment as a between-participants and within-items variable, in addition to the variables distractor type and SOA (short: 0 ms; long: 350 and 1000 ms). As in the separate analyses for each experiment, RTs were longer in the related than in the unrelated condition, $F_1(1,38) = 22.72$, $MSE = 1294$, $p < .001$, $F_2(1,31) = 8.66$, $MSE = 5481$, $p = .007$; and longer at short than at long SOAs, $F_1(1,38) = 238.55$, $MSE = 7281$, $p < .001$, $F_2(1,31) = 826.38$, $MSE = 3272$, $p < .001$. SOA and experiment interacted, $F_1(1,38) = 6.36$, $MSE = 7281$, $p = .016$, $F_2(1,31) = 41.89$, $MSE = 1321$, $p < .001$.

Crucially, the effect of distractor type was dependent on SOA, $F_1(1,38) = 8.76$, $MSE = 828$, $p = .005$, $F_2(1,31) = 6.21$, $MSE = 1498$, $p = .018$, but not on experiment, both *F*s < 1. The three-way interaction of distractor type, SOA, and experiment was not significant, both *F*s < 1. These findings together indicate that the magnitude of the semantic interference effect depended on SOA to the same extent for both experiments. With the data of the two experiments combined for the 0-ms SOA, the semantic interference effect was still not significant at the 0-ms SOA, $F_1(1,38) = 2.82$, $MSE = 1318$, $p = .101$, $F_2(1,31) = 2.31$, $MSE = 3083$, $p = .139$. The magnitude of the semantic interference effect did not differ between the 350-ms and the 1000-ms SOAs, $t_1(38) = 1.13$, $p = .266$, $t_2(62) < 1$. For the 0-ms SOAs, there was also no difference in effects between experiments, *t*s < 1.

To conclude, the semantic interference effect was statistically absent at the 0-ms SOA, whereas it was present and of comparable magnitude at the 350-ms and 1000-ms SOAs.

5. Analyses of RT Distributions

Previous research suggested that null effects in mean RTs may be the result of opposite effects in the leading edge and the tail of an RT distribution (e.g., Heathcote et al., 1991;

Roelofs, 2012). Whether this is the case for the picture-naming RTs of the present experiments was investigated with Vincentile analyses. Figure 4 gives the Vincentised cumulative distribution curves for Experiments 1 and 2 as a function of SOA and distractor type. At the 350-ms and the 1000-ms SOAs, the related condition was slower than the unrelated condition throughout the RT distribution, except for the 20% fastest responses (where there is no visible difference). At the 0-ms SOAs, the distractor conditions are highly overlapping, showing a general absence of semantic interference throughout the RT distribution. Thus, the Vincentile analyses show that the absence of a semantic interference effect in the mean RTs at the 0-ms SOA is not the result of opposing effects in the leading edge and the tail of the RT distribution. Rather, the semantic interference effect is absent throughout the RT distribution.

6. Task-Set Reconfiguration

Task-set reconfiguration occurs in paradigms where the task to be performed is not fixed, but rather changes on a trial-by-trial basis, such as in the case of the task-choice paradigm employed here. There is some evidence suggesting that such task-set reconfiguration may hamper perceptual processing (Vachon, Tremblay, & Jones, 2007). One could thus argue that, at the 0-ms SOA, the reconfiguration of a task set decreased the efficiency of perceptual encoding, explaining why the semantic interference effect was absent at the 0-ms SOA. Under such account, the semantic interference effect should be especially absent on switch trials, that is, when the task of the current trial is different from the task of the previous trial. On repeat trials (same task on two consecutive trials), however, the task set does not need to be reconfigured, so perceptual encoding should not be affected, and semantic interference should be observed.

To assess the merits of this alternative explanation, the effect of task-set reconfiguration was examined. The results of Experiment 1 and 2 were re-analysed with task set (the task of the previous trial is repeated or the task is switched) as an additional within-participants independent variable.

6.1. Experiment 1

Responses were on average 32 ms slower on switch than on repeat trials, $F_1(1,19) = 23.2$, *MSE* = 3602, $p < .001$. The task switch costs were larger at the 0-ms (40 ms) than at the 1000-ms (25 ms) SOA, $F_1(1,19) = 5.16$, *MSE* = 1004, $p = .035$; and also larger for word reading (86 ms) than for picture naming (22 ms), $F_1(1,19) = 59.8$, *MSE* = 3900, $p < .001$. The switch costs across the two tasks were numerically larger for unrelated (41 ms) than related (23 ms) stimuli, but did not statistically differ in magnitude, $F_1(1,19) = 3.56$, *MSE* = 1860, $p = .075$. Only the three-way interaction between task, SOA, and task set was significant, $F_1(1,19) = 7.02$, *MSE* = 3714, $p = .016$. Crucially, no further interactions involving distractor type and task set were observed, all *p*s > .252. Thus, the absence of a semantic effect at SOA = 0 ms was observed for both switch and repeat trials. These results indicate that although task switch costs were obtained, the absence of semantic interference at the short SOA was not due to task switching.

6.2. Experiment 2

Responses were on average 37 ms slower on switch than on repeat trials, $F_1(1,19) = 21.9$, *MSE* = 5184, $p < .001$. The task switch costs were numerically larger at the 0-ms (50 ms) than at the 1000-ms (26 ms) SOA, although this difference did not reach statistical significance, $F_1(1,19) = 3.17$, *MSE* = 3415, $p = .091$. The switch costs were also larger for word reading (95 ms) than for picture naming (-19 ms), $F_1(1,19) = 120.6$, *MSE* = 2131, $p < .001$. The switch costs were of similar magnitude for related (35 ms) and unrelated (41 ms) stimuli, $F_1(1,19) < 1$, *MSE* = 1302, $p = .483$. No further interactions were observed, all *p*s > .414. Thus, the absence of a semantic effect at the 0-ms SOA was observed for both switch and repeat trials.

These results thus converge with those of Experiment 1: Although task switch costs were obtained, the absence of semantic interference at the short SOA was not due to task switching.

In summary, in both experiments the semantic interference effect was absent at the 0-ms SOA on both switch and repeat trials. These findings refute the account that the absence of semantic interference at the 0-ms SOA is due to inefficient perceptual processing caused by task-set reconfiguration.

7. General Discussion

In the present study, we used a task-choice procedure (Besner & Care, 2003) which, in contrast to PRP experiments, does not require that two responses are made on each trial (i.e., a response to the tone and a response to the picture-word stimulus). Rather, only a single response needs to be made at each trial, and this response depends on a task choice. We tested the account put forward by Piai, Roelofs, and Schriefers (2011, 2014) that in this latter case semantic interference in picture naming should be obtained at long SOAs (i.e., a clear preexposure of the task cue), but not at an SOA of 0 ms. In two experiments, participants decided between picture naming and word reading based on a tone. The tone was either presented simultaneously with the picture-word stimulus, or 1000 or 350 ms before it. If the effects of distractor type and SOA in previous PRP experiments (Kleinman, 2013; Piai & Roelofs, 2013; Piai, Roelofs, & Roete, 2014; Piai, Roelofs, & Schriefers, 2014; Schnur & Martin, 2012; van Maanen et al., 2012) were additive because speakers have a strong preference not to overlap response selection in picture naming with response selection in another task (i.e., a response-selection bottleneck), then the effects should be underadditive when using the task-choice procedure. That is, semantic interference should disappear or be reduced at the 0-ms SOA, but not at the 350-ms SOA and at longer SOAs. These predictions were borne out by our results. The semantic interference effect was substantially reduced and statistically not significant at the 0-ms SOA in the mean RTs and throughout the RT distributions. In contrast, at the 350-ms and 1000-ms SOAs, a full-blown semantic effect was observed. The size of the semantic interference effect did not differ statistically between the 350-ms and 1000-ms SOAs. This pattern of results not only replicates the findings of Piai et al. (2011) using the task-choice procedure, but extends them by showing that the semantic interference effect is either present or absent in the same group of participants as a function of when the task cue was presented (i.e., SOA). Moreover, we now show that the semantic interference effect is absent at the 0-ms SOA throughout the RT distribution and absent at this SOA regardless of whether a task-set reconfiguration is required (switch trials) or not (repeat trials).

The present results support the account of Piai, Roelofs, and Schriefers (2011, 2014): Although speakers strongly prefer response selection processes in picture naming not to overlap with response selection in another task, they do allow response selection in picture naming to overlap with task-choice processes. These latter processes have mainly been characterised as decoding the cue and implementing a task set (O'Malley & Besner, 2011). Whether cue decoding and task-set implementation occur serially or in parallel is still an open question. Relevant for the present article, however, is whether cue decoding and task-set implementation can occur in parallel with response selection for picture naming.

Using tones to indicate whether the task to be performed on written words was reading aloud or a case decision (i.e., deciding whether words are in upper or lower case), O'Malley and Besner (2011) obtained evidence that lexical processing proceeds in parallel with the task-choice process. They observed that word frequency had a smaller effect at the 0-ms SOA than at a 750-ms SOA. However, when nonwords were randomly intermixed with the words, the effects of word frequency and SOA were additive (O'Malley & Besner, 2012). These findings suggest that participants may strategically determine whether or not to allow an overlap of task choice and word processing, depending on the prevailing experimental circumstances (i.e., whether the experiment includes words only or also nonwords). This is in line with the proposal of Piai, Roelofs, and Schriefers (2011, 2014; Roelofs & Piai, 2011) that participants strategically determine whether or not to select responses in a picture naming task while concurrently processing other stimuli.

Two alternative accounts for our findings of underadditivity could be ruled out on empirical grounds. According to the first account, the null effect in the mean RTs at the 0-ms SOA could be the result of opposite effects in the leading edge and the tail of the RT distribution. Using Vincentile analyses, we showed that at the 0-ms SOA, the semantic interference effect was absent throughout the picture-naming RT distribution. Thus, the absence of a semantic interference effect in the mean RTs at the 0-ms SOA is not the result of opposing effects in the leading edge and the tail of the RT distribution.

According to the second account, at the 0-ms SOA, reconfiguring the task set (picture naming vs word reading) could have decreased the efficiency of the perceptual encoding of the distractor word. If the distractor word is poorly perceived, it does not influence picture naming RTs so strongly, which could explain why the semantic interference effect was absent at the 0-ms SOA. If task-set reconfiguration reduces the efficiency of perceptual processing, we would expect this reduction to be especially present on trials where the task set has to be reconfigured (i.e., switch trials). However, additional analyses demonstrated that the semantic interference effect was absent at the 0-ms SOA on both switch and repeat trials, allowing us to reject this alternative explanation.

We now turn to a third alternative account of our findings, which assumes that the semantic interference effect emerges at pre-selection stages (cf. Dell'Acqua et al., 2007). According to this account (and differently from Figure 2), the task-choice process precludes concurrent response selection in picture naming. Under the assumption that the semantic interference effect emerges at pre-selection stages, its absence at the 0-ms SOA could then be interpreted in terms of absorption into slack. However, although this account can explain the present findings, it leaves unexplained the finding of additive effects of SOA and distractor type in dual-task PRP experiments (Kleinman, 2013; Piai & Roelofs, 2013; Piai, Roelofs, & Roete, 2014; Piai, Roelofs, & Schriefers, 2014; Schnur & Martin, 2012; van Maanen et al., 2012).

In the introduction, we presented the assumption that picture and word processing initially proceed in parallel until the word-form encoding stage (for discussion, see Piai et al., 2011). The literature suggests that oral word reading minimally requires orthographic processing (i.e., input processing, including feature, letter, and lexical form processing) and word-form encoding (i.e., output processing, including morphological, phonological, and phonetic encoding), but can be accomplished without lemma (i.e., lexical response) selection (cf. Roelofs, 2003, 2004). Thus, we assumed that orthographic processing of the word and response selection for the picture occur simultaneously with the task decision process, whereas word-form encoding is postponed until the task (i.e., word reading or picture naming) is known. An alternative assumption would be that participants always prepare only the more difficult task (i.e., picture naming) and thus have to revise their choice on half of the trials (since we had an equal number of picture naming and word reading trials). Under this scenario, virtually all reading trials would be associated with revised choices, which prolongs RTs. This scenario would predict especially long RTs for the reading task at the 0-ms SOA relative to the long SOAs and relative to picture naming (the cases when no revision is required). A second alternative is that speakers variably commit either to word or picture processing across trials and revise this choice if needed after cue processing. Under this second alternative scenario, we should find especially long RTs for both the reading and naming tasks at the 0-ms SOA relative to the long SOAs (when no revision is required).

To assess these hypotheses, we examined the Vincentised cumulative RT distribution curves for both experiments as a function of SOA and task (collapsed over distractor type), which are presented in Figure 5. Of particular interest are the slopes between the .8 and 1.0 points of the cumulative distributions, which indicate the slowest responses in each task. As can be seen, RTs at the 0-ms SOA are not disproportionally longer than at the long SOAs, as indicated by the parallelism between the curves. Statistical analysis revealed that there was no difference between the slopes, all ps > .104. Thus, in the absence of any evidence that task choices are revised, we maintain the assumption that picture and word processes initially proceed in parallel until a certain stage (i.e., word-form encoding), but more research is certainly needed to further clarify this issue.

Findings from several studies support the conclusion that the semantic interference effect does not emerge at pre-selection stages, but rather during response-selection or later (see for extensive discussion Piai, Roelofs, & Schriefers, 2014). The account proposed here is consistent with conclusions from previous studies using the PRP procedure. Importantly, the PRP procedure differs from the task-choice procedure in that response selection to the tone stimulus (S1) is required for the former but not for the latter procedure. Here, we show that by changing the response requirement for the tone stimulus (from response selection into no response selection), a different pattern of effects emerges (underadditive rather than additive effects of SOA and distractor type). Therefore, we favour an account that leaves the locus of the semantic interference effect unchanged (i.e., it arises during response selection or later). According to this account, the type of nonlinguistic processing (i.e., involving response selection or not) for the first stimulus (S1) determines how much overlap with response selection in picture naming (S2) is tolerated.

In summary, we observed a semantic interference effect in picture naming when the tone (cueing participants about the task to be performed), was presented before the picture-word stimulus. However, the semantic interference effect was absent when tone and picture-word stimulus were presented simultaneously. By contrast, in our previous experiments with manual responding to the tone, the semantic interference effect was present regardless of whether the tone was presented simultaneously with the picture-word stimulus or not (Piai, Roelofs, & Roete, 2014; Piai, Roelofs, & Schriefers, 2014; see also Kleinman, 2013; Schnur & Martin, 2012). Taken together, these results support an account according to which speakers tend to avoid concurrent response selection in picture naming and another task, but they do not avoid response selection in picture naming and other types of concurrent processing, such as task choices.

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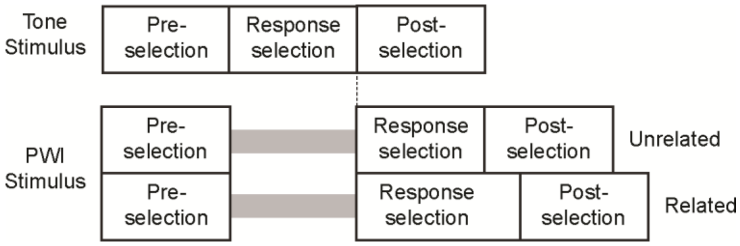
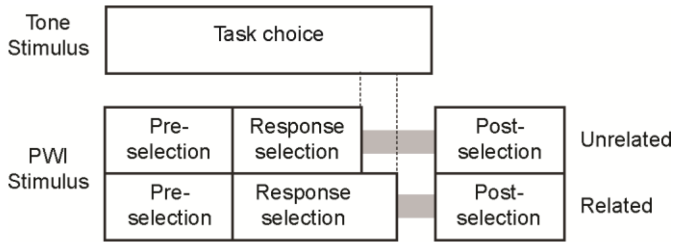
Table 1

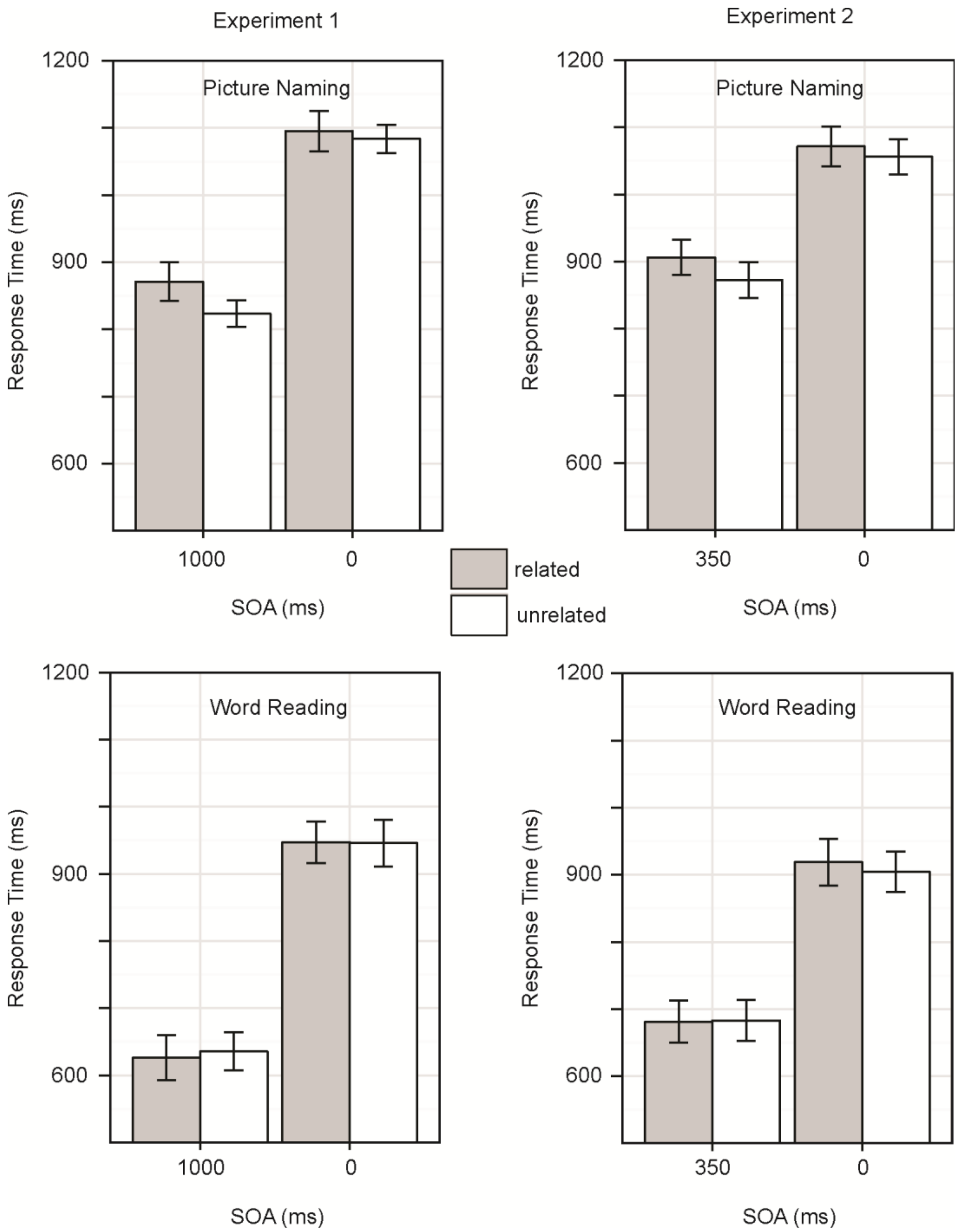
Percent Error for Picture Naming and Word Reading per Stimulus Onset Asynchrony (SOA) and Distractor Type in Experiments 1 and 2.

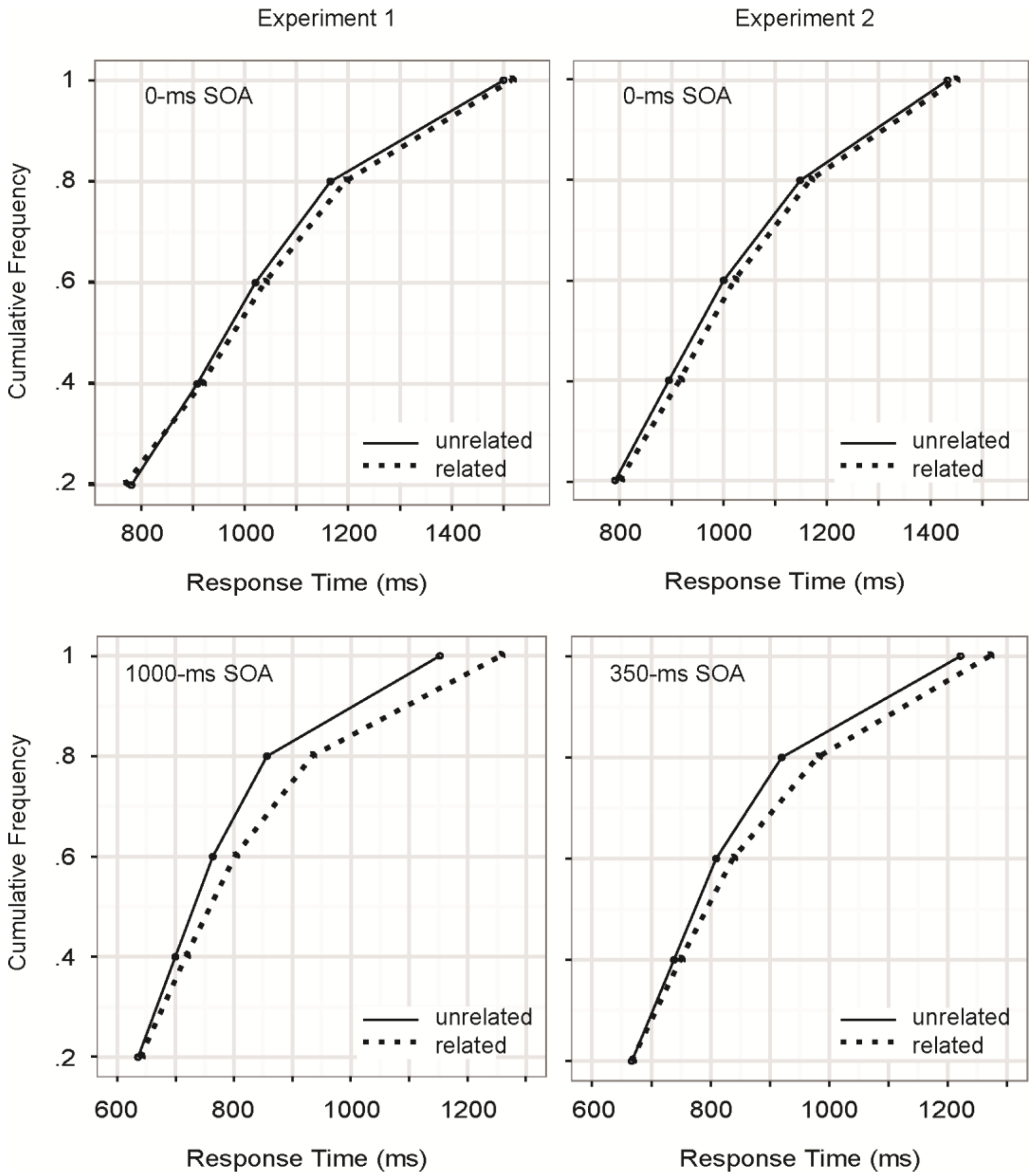
	Experiment 1		Experiment 2	
	Picture Naming			
Distractor Type	SOA 1000 ms	SOA 0 ms	SOA 350 ms	SOA 0 ms
Related	6.0	9.2	12.5	13.2
Unrelated	5.5	7.8	11.0	12.1
Difference	0.5	1.4	1.5	1.1
	Word Reading			
Distractor Type	SOA 1000 ms	SOA 0 ms	SOA 350 ms	SOA 0 ms
Related	3.6	4.8	5.1	11.5
Unrelated	4.1	4.8	6.5	11.9
Difference	-0.5	0	-1.4	-0.4

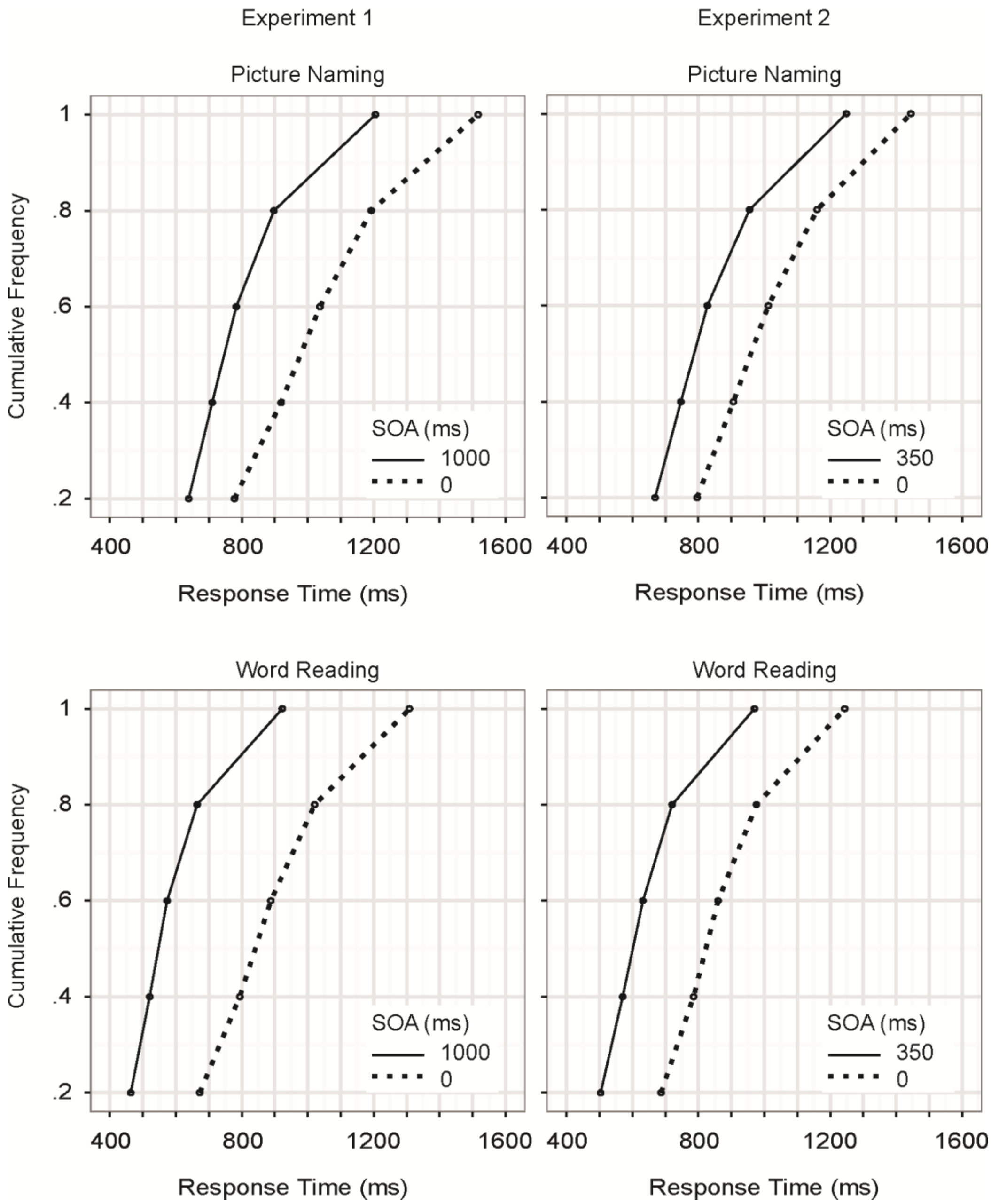
Note. Mean response times are given in milliseconds.


Tone Stimulus
Pre-selection
Response selection
Post-selection
PWI Stimulus
Pre-selection
Response selection
Post-selection
Unrelated
Pre-selection
Response selection
Post-selection
Related


Tone Stimulus
Task choice
PWI Stimulus
Pre-selection
Response selection
Post-selection
Unrelated
Pre-selection
Response selection
Post-selection
Related


Experiment 1
Experiment 2
Picture Naming
Picture Naming
Word Reading
Word Reading
Response Time (ms)
1200
900
600
1000
0
350
SOA (ms)
related
unrelated


Experiment 1
Experiment 2
0-ms SOA
0-ms SOA
1000-ms SOA
350-ms SOA
Cumulative Frequency
Response Time (ms)
unrelated
related
1
.8
.6
.4
.2
600
800
1000
1200
1400



Experiment 1
Experiment 2
Picture Naming
Picture Naming
Word Reading
Word Reading
Cumulative Frequency
Response Time (ms)
SOA (ms)
1000
350
0
400
800
1200
1600
.2
.4
.6
.8
1

Figure Captions

Figure 1. Schematic illustration of the slack logic for the psychological refractory period (PRP) procedure at SOA = 0 ms applied to semantic interference in picture naming. Pre-selection refers to the stages of perceptual and conceptual encoding. Post-selection for the tone stimulus refers to the stages of response programming and execution and for the picture stimulus to the stages of word-form encoding and articulation. The distractor types are given to the right of the figure. The shaded areas indicate slack. The figure illustrates the assumption that semantic interference arises in response selection and is reflected in the response times, as assumed by Piai, Roelofs, and Schriefers (2014).

Figure 2. Schematic illustration of the slack logic for the task-choice procedure at SOA = 0 ms applied to semantic interference in picture naming. Pre-selection refers to the stages of perceptual and conceptual encoding. Post-selection for the tone stimulus refers to the stages of response programming and execution and for the picture stimulus to the stages of word-form encoding and articulation. The distractor types are given to the right of the figure. The shaded areas indicate the slack. The figure illustrates that the semantic interference effect is absorbed into slack created by the task-choice process, as assumed by Piai et al. (2011).

Figure 3. Normalised mean response times for picture naming (upper panels) and word reading (lower panels) as a function of SOA and distractor type for Experiment 1 (left panels) and Experiment 2 (right panels). Error bars indicate 95% confidence intervals. Normalised means and 95% confidence intervals were calculated with the Cousineau-Morey approach (Morey, 2008).

Figure 4. Vincentised cumulative distribution curves for picture naming in the related and unrelated distractor type conditions as a function of SOA for Experiment 1 (left panels) and Experiment 2 (right panels).

Figure 5. Vincentised cumulative distribution curves for picture naming (top) and word reading (bottom) as a function of SOA for Experiment 1 (left panels) and Experiment 2 (right panels).