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On the Flexibility of Grammatical Advance Planning During Sentence Production: Effects of Cognitive Load on Multiple Lexical Access

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Three picture–word interference experiments addressed the question of whether the scope of grammatical advance planning in sentence production corresponds to some fixed unit or rather is flexible. Subjects produced sentences of different formats under varying amounts of cognitive load. When speakers described 2-object displays with simple sentences of the form “the frog is next to the mug,” the 2 nouns were found to be lexically–semantically activated to similar degrees at speech onset, as indexed by similarly sized interference effects from semantic distractors related to either the first or the second noun. When speakers used more complex sentences (including prenominal color adjectives; e.g., “the blue frog is next to the blue mug”) much larger interference effects were observed for the first than the second noun, suggesting that the second noun was lexically–semantically activated before speech onset on only a subset of trials. With increased cognitive load, introduced by an additional conceptual decision task and variable utterance formats, the interference effect for the first noun was increased and the interference effect for second noun disappeared, suggesting that the scope of advance planning had been narrowed. By contrast, if cognitive load was induced by a secondary working memory task to be performed during speech planning, the interference effect for both nouns was increased, suggesting that the scope of advance planning had not been affected. In all, the data suggest that the scope of advance planning during grammatical encoding in sentence production is flexible, rather than structurally fixed.

Keywords: sentence production, lexical access, lemma retrieval, grammatical encoding, picture–word interference

In his famous essay “Über die allmähliche Verfertigung der Gedanken beim Reden” (On the Gradual Production of Thoughts Whilst Speaking), von Kleist (1878/1990) speculated that speakers have not fully prepared an utterance by the time they start producing the first word. In fact, it is a fundamental assertion of recent speech production models that utterance generation proceeds in an incremental (or piecemeal) fashion (e.g., Levelt, 1989). A lot of psycholinguistic research over the last 4 decades has been devoted to determining how far ahead speakers do plan and whether advance planning might differ at different representational levels (e.g., Allum & Wheeldon, 2007, 2009; Brown-Schmidt & Tanenhaus, 2006; Costa & Caramazza, 2002; Damian & Dumay, 2007; Dell & O’Seadhgha, 1992; F. Ferreira, 1991; Ford & Holmes, 1978; Garrett, 1980; Griffin & Bock, 2000; Lindsley, 1975, 1976; Martin, Miller, & Vu, 2004; Meyer, 1996; Oppermann, Jescheniak, & Schriefers, 2008; Schnur, Costa, & Caramazza, 2006; Schriefers, Teruel, & Meinshausen, 1998; Smith & Wheeldon, 1999, 2004; Wheeldon & Lahiri, 2002).

The available evidence on the scope of advance planning provides a rather inconsistent picture with respect to the level of grammatical encoding (see below). This situation has led some researchers to propose that the language production system is flexible, such that speakers can adapt the scope of advance planning to the current circumstances (e.g., F. Ferreira & Swets, 2002; Levelt, 2001; Levelt & Meyer, 2000; Lindsley, 1976; Mortensen, Meyer, & Humphreys, 2008). In the present paper, we put this notion to a direct test. In particular, we explore which abstract lexical representations (also referred to as lemmas) are selected prior to speech onset under different amounts and types of cognitive load. We thus follow the general assumption in research on grammatical advance planning that the scope of grammatical advance planning controls which lemmas are accessed prior to utterance onset (e.g., Allum & Wheeldon, 2007, 2009). The main question of interest was whether the advance planning scope of grammatical encoding is structurally fixed or whether speakers flexibly adapt the scope of grammatical advance planning to the demands of the speaking situation.

In the following, we first provide a brief review of extant studies on advance planning during grammatical encoding. This review sets the stage for a series of three picture–word interference experiments that explored whether the scope of advance lemma

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selection (and thus grammatical encoding) varies as a function of cognitive load.

Grammatical Advance Planning During Sentence Production

Initial evidence regarding the scope of grammatical advance planning came from the analyses of speech errors (e.g., Garrett, 1975, 1976, 1980). In particular, word exchange errors, which are assumed to arise during grammatical encoding, were found to regularly involve words from different phrases, suggesting that these words were simultaneously processed and thus that grammatical advance planning exceeds a single phrase. Results from the analysis of pause distribution patterns in spontaneous connected speech are also in line with this view (see Boomer, 1965; Butterworth, 1980; Ford, 1982; Goldman-Eisler, 1968).

First experimental studies on grammatical advance planning compared speech onset latencies for different utterance formats. In a study by Kempen and Huijbers (1983; for similar experiments, see also Lindsley, 1975, 1976), subjects saw simple action scenes (e.g., a man teasing a boy) and were instructed either to name the actor ("the man") or the action ("teasing") or to name the actor and the action ("the man teases"). Kempen and Huijbers found that actor naming was faster than both action naming and actor–action naming, which did not differ from one another. From this pattern, they concluded that the lemma of the verb of a subject–verb utterance is accessed before speakers start articulation. Following up on these studies, Smith and Wheeldon (1999, see also Levelt & Maassen, 1981) used moving pictures of objects instead of static action scenes. The critical comparison was between utterances containing a simple initial noun phrase (e.g., "the dog") and those containing a complex initial noun phrase (e.g., "the dog and the foot") while controlling for overall utterance length. Sentences with a simple initial noun phrase were produced faster than those with a complex initial noun phrase, suggesting a phrasal planning scope (for a replication and extension of these results, see Allum & Wheeldon, 2007, 2009). Further support for a phrasal planning scope comes from a study by F. Ferreira (1991). In this study, subjects recalled sentences, which had simple or complex noun phrases in either sentence initial or sentence final position, from memory. Speech onset latencies were longer for sentences with complex initial noun phrases than for sentences with simple initial noun phrases. By contrast, the complexity of the sentence final noun phrases did not affect utterance onset latencies, suggesting that the sentence final noun phrase had not been planned before speech onset and thus that the scope of grammatical advance planning is smaller than a subject–verb–object sentence.

A second type of experimental study used an extension of the picture–word interference paradigm (e.g., Schriefers, Meyer, & Levelt, 1990). Meyer (1996) presented displays of two objects appearing side by side and instructed her subjects to name the objects from left to right by producing a simple sentence (e.g., "the dog is beside the suitcase") or a coordinated noun phrase (e.g., "the dog and the suitcase"). While subjects prepared the naming response, a distractor word was presented; it could be semantically related or unrelated to the first or second noun of the utterance (i.e., to the left object or to the right object, respectively). Meyer observed interference from semantically related distractors for both noun positions compared to an unrelated distractor condition, and these interference effects did not differ significantly in size. This semantic interference effect is assumed to reflect difficulties in lexical (i.e., lemma) selection (e.g., Damian & Bowers, 2003; Levelt, Roelofs, & Meyer, 1999; Roelofs, 1992; Starreveld & La Heij, 1995, 1996). Thus, Meyer concluded from her data pattern that the stage of grammatical encoding has a clausal planning scope.[1]

In another study, Smith and Wheeldon (2004) presented their subjects with a picture (e.g., of a saw) and a word (e.g., *cat*) on each trial. These stimuli either moved together in the same direction or moved toward each other. Depending on the movement, the subjects described the stimuli as "the saw and the cat move down" or "the saw moves toward the cat." Thus, picture and word appeared either in the same phrase or in different phrases. Furthermore, picture and word were semantically related or unrelated. Smith and Wheeldon found a delay in naming latencies for the related condition, independent of the type of sentence produced. Such a delay suggests a clausal planning scope.

Using an extended picture–word interference paradigm, Schriefers et al. (1998) addressed the question of whether the verb is obligatorily selected before sentence onset, as proposed by Bock and Levelt (1994; see also Kempen & Huijbers, 1983, and Lindsley, 1975, 1976). The subjects described pictures of simple scenes (an actor performing an action or an actor performing an action with an object). The word order of the target utterances was systematically manipulated (verb in utterance initial position or in utterance final position). In addition, speakers were presented with verbs as distractor words that were semantically related or unrelated to the verb of the picture description. Semantic interference was obtained only for utterances with verbs in utterance initial position and not for utterances with verbs in utterance final position. From this pattern, Schriefers et al. concluded that the verb is not automatically and obligatorily part of the grammatical advance planning.

In summary, the extant studies leave us with an inconsistent picture. Some of the just mentioned studies suggest a clausal scope (Boomer, 1965; Butterworth, 1980; Ford, 1982; Garrett, 1975, 1976, 1980; Goldman-Eisler, 1968; Meyer, 1996; Smith & Wheeldon, 2004), others a phrasal scope (Allum & Wheeldon, 2007, 2009; F. Ferreira, 1991; Meyer, 1997; Schriefers et al., 1998; Smith & Wheeldon, 1999), and still others a scope including the initial noun phrase and the verb (Kempen & Huijbers, 1983; Lindsley, 1975, 1976).

This diversity of findings could suggest that speakers are not using an advance planning unit of some fixed size but rather are able to flexibly adapt the scope of grammatical advance planning to the demands of the speaking situation. Although this possibility has been voiced repeatedly in the literature (see F. Ferreira & Swets, 2002; Levelt, 2001; Levelt & Meyer, 2000; Lindsley, 1976; Mortensen et al., 2008) by those providing post hoc accounts for the discrepancies among studies, it has as yet not been put to a

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[1] One could speculate whether the semantic effect has a conceptual rather than a lexical origin. However, it has been demonstrated that the effect is confined to lexical tasks and disappears with nonlexical, conceptual tasks (see Damian & Bowers, 2003; Schriefers et al., 1990).

direct experimental test.[2] Such a direct test was our aim in the experiments reported in this article.

Overview of the Experiments

A variant of the cross-modal picture–word interference paradigm was used in the present experiments. Subjects viewed pairs of (colored) line drawings of objects presented side by side and described them as quickly as possible with a sentence of the form "the [left object] is next to the [right object]" (e.g., "the frog is next to the mug"). In some experiments, subjects were asked to include the color information in their description, producing utterances of the form "the [color] [left object] is next to the [color] [right object]" (e.g., "the blue frog is next to the blue mug"). Subjects also heard auditory distractor words (presented at different stimulus onset asynchronies; SOAs) that they were instructed to ignore. The relation between object names and distractors was systematically varied. Distractors could be either semantically related or unrelated to the name of the (left) object to be named in first position (e.g., *toad* or *horn*) or could be semantically related or unrelated to the name of the (right) object to be named in second position (e.g., *cup* or *sock*). In single-object naming tasks, semantically related distractors typically interfere with the naming process, and the effect is taken as an index of difficulties during selecting the lexical (lemma) representation of the respective word (e.g., Damian & Bowers, 2003; Jescheniak, Schriefers, & Hantsch, 2003; La Heij, Kuipers, & Starreveld, 2006; Levelt, 2001; Levelt et al., 1999; Meyer, 1996; Roelofs, 1992, 1997; Schriefers et al., 1990; for a different view, see Finkbeiner & Caramazza, 2006, and Mahon, Costa, Peterson, Vargas, & Caramazza, 2007). As mentioned above, for visual displays and sentences such as the ones used in the present study, Meyer (1996) observed similarly sized semantic interference effects for both nouns. This result suggests that both lemmas were selected before speech onset and thus that the scope of grammatical advance planning extends over a whole (simple) sentence. This observation is the starting point of the experiments reported below.

Experiment 1a was a replication of the experiment by Meyer (1996, Experiment 2) conducted in a different language (German instead of Dutch) and with new materials. Subjects produced sentences such as "the frog is next to the mug" (henceforth referred to as simple sentences). The experiment sought to establish semantic interference effects for nouns appearing in the first position as well as for nouns appearing in the second position. This experiment replicated the results of Meyer (1996, Experiment 2), yielding similar-sized semantic interference effects for both nouns. In Experiment 1b, we explored whether the same pattern obtains for a similar type of utterances with more complex noun phrases by including the color information in form of prenominal adjectives (e.g., "the blue frog is next to the blue mug"; henceforth referred to as complex sentences). Their inclusion increased the demands on conceptual and formulation processes.

Experiment 1c was devised to show that the pattern of results of Experiment 1b does not depend on the use of the same color adjective in both noun phrases of complex utterances. Therefore, in Experiment 1c, the objects were depicted in different colors, resulting in sentences such as "the red frog is next to the blue mug."

In Experiment 2, subjects additionally performed a conceptual decision task; they had to decide whether the natural size of the depicted objects was smaller or larger than a given standard. The outcome of this task determined the format of the utterance (simple or complex utterance). Thus, unlike Experiments 1a, 1b, and 1c, Experiment 2 required subjects to switch between utterance formats, which increased cognitive load. Experiment 2 introduced a cognitive load manipulation that was directly related to the to-be-produced response (a switch in utterance formats), but a standard dual-task approach was used in Experiment 3. Subjects produced simple sentences as they simultaneously performed a working memory task; subjects retained a set of either five digits (in Experiment 3a) or five adjectives (in Experiment 3b) in working memory while being engaged in speech planning.

If the scope of grammatical advance planning is fixed and independent of the variations of cognitive load introduced in the different experiments, the pattern of interference effects for the first and the second noun for simple utterances in Experiments 2 and 3 should resemble the one observed in Experiment 1a and the pattern for complex utterances in Experiment 2 should resemble the one obtained in Experiments 1b and 1c. If, by contrast, speakers adapt themselves to an increase in cognitive load by readjusting the scope of grammatical advance planning, the relative interference pattern for the first and the second noun for a given utterance format should differ across experiments. One straight prediction would be that under conditions of enhanced cognitive load the scope of advance planning is narrowed down, possibly to the initial noun phrase. If so, one should obtain semantic interference for the first noun only, and the interference effect for the second noun should disappear (as that noun is no longer being retrieved before speech onset). However, given that the issue of advance planning is not well understood and there are no explicit computational models that would allow for firm predictions, one could also speculate whether the scope of advance planning is enlarged with increasing cognitive load. The basic idea here is that under rather light processing conditions (i.e., in the absence of additional cognitive load) speakers might be able to proceed quickly and efficiently in an incremental fashion. That is, under such circumstances a speaker might be able to plan later parts of an utterance while articulating the initial part of the utterance. Additional cognitive load, however, might make such incremental production (i.e., articulation of the utterance initial parts and planning of later parts in parallel) more difficult or impossible, such that speakers would be forced to prepare the entire utterance before initiating the response. This scenario would thus predict a larger advance planning scope as cognitive load is increased and thus enhanced

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[2] There is one study investigating the effect of time pressure on phonological advance planning (Damian & Dumay, 2007), which failed to obtain evidence in favor of flexibility in advance planning. Note, however, that this study differs in a number of important respects from the present one. First, it focused on a different representational level (phonological rather than syntactic); second, it manipulated time pressure as opposed to cognitive load (which was in the focus of the present study); and third, it was limited to advance planning within a single syntactic phrase (as opposed to a sentence).

interference effects for the second noun.[3] Regardless of which of these two possibilities holds, the important point is that any flexibility in the scope of grammatical advance planning should manifest itself in terms of differences in semantic interference effects for nouns appearing later in a sentence as a function of cognitive load.

Experiments 1a and 1b

Experiment 1a was a replication of Meyer (1996, Experiment 2) conducted with new materials and in a different language but with the same type of visual display and utterance format, namely, "the [left object] is next to the [right object]" (e.g., "the frog is next to the mug"). Experiment 1b was an extension with a slightly more complex utterance format, namely, "the [color] [left object] is next to the [color] [right object]." To the extent that the pattern observed by Meyer is replicated, similar-sized interference effects from distractors semantically related to the first or the second noun should be obtained in Experiment 1a. If these results also generalize to utterances with more complex noun phrases, the same should hold for Experiment 1b.

Method

Subjects. Forty-eight subjects were tested in this experiment, half of them in Experiment 1a and half of them in Experiment 1b. All were native speakers of German and students from the University of Leipzig. They were paid 8 EUR (approximately US$11.50) for participation or received course credit. They had no known hearing deficit and had normal or corrected-to-normal vision. In these and all other experiments reported in this article, subjects were replaced according to the following adaptive criterion, which we applied to account for differences in task difficulty across experiments. We determined the mean plus 2 standard deviations (*SD*s) for naming latencies and error rates, based on the first 24 subjects tested in an experiment, and rounded these values to the next 50 ms or next full percent. Subjects were replaced if either their mean naming latencies or their error rates exceeded this criterion (see also Jefferies, Ralph, & Baddeley, 2004; Park, Kim, & Chun, 2007). Moreover, to retain sufficient observations for the analyses of naming latencies, we set the absolute upper limit for error rates at 25% for simple sentence production and 33% for complex sentence production. After these criteria were applied, two subjects were replaced in Experiment 1a and one subject was replaced in Experiment 1b. No subject took part in more than one of the experiments reported in this article.

Materials. Thirty-two line drawings of simple objects were selected such that they could also be used in a task in which the natural size of the objects would determine utterance format (i.e., Experiment 2). For 16 objects, the natural size of typical exemplars was larger than a given standard (a box with width × height × depth = 26.5 cm × 18 cm × 12.5 cm); for the other 16 objects, it was smaller than the standard. This classification was validated in a norming study performed with an independent sample of subjects ($N = 16$). Subjects indicated on a 5-point scale whether typical exemplars of the depicted object category were larger or smaller than the standard (1 = *always smaller* to 5 = *always larger*). Subjects classified the objects as expected in 92.2% of cases (i.e., either with values of 1 or 2 for objects that we had considered small or with values of 4 or 5 for objects that we had considered large). Line drawings of the individual pictures were sized to fill an imaginary square of about 8 × 8 cm. The individual pictures were combined into pairs in such a way that (a) the two objects always belonged to the same natural-size class and (b) the two objects were neither semantically nor phonologically related. Each picture was included in two pairs, once as the object to which the distractors were related and once as the object to which the distractors were not related.[4] The object pairs were presented in three colors. Of the 32 object pairs presented, 11 were red, 11 were green, and 10 were blue. The midpoint-to-midpoint distance of the drawings was 8 cm. There were eight more objects, combined into eight pairs, to be used in training and warm-up trials.

For each object, a semantically related (but phonologically unrelated) distractor word was selected; this word denoted a category coordinate or a near-synonym. (Objects and distractors used in Experiments 1–3 are given in Appendix A.) The distractor word was semantically, associatively, and phonologically unrelated to the other object in the display. Unrelated distractors were created by reassigning the semantically related distractors to other object pairs such that there was no semantic, associative, or phonological relation to any of the objects in the respective pair. As the German target utterances contained gender-marked determiners, we also controlled for possible gender congruency effects (e.g., Schriefers, 1993) by keeping the grammatical gender of related and unrelated distractors identical for a given object (and different from the grammatical gender of the other object in the pair). The acoustic distractor words were spoken by a female native speaker of German. They varied in duration from 429 ms to 747 ms, with an average of 597 ms ($SD = 83$ ms). The auditory materials were digitized at a sampling rate of 48 KHz and were stored on the hard disk of a computer for presentation during the experiment.

Design. In each subexperiment, there were three factorially crossed variables: relatedness (2 levels, semantically related distractors vs. unrelated distractors), noun position (2 levels, distractors related or unrelated to the noun in position 1 vs. related or unrelated to the noun in position 2), and SOA (3 levels, –100 ms, 0 ms, and 100 ms; negative SOA indicates onset of the distractor before picture onset, and positive SOA indicates distractor onset after picture onset). The SOA manipulation was included because we expected differences in speech onset latencies as a function of task demands. By manipulating SOA, we meant to rule out the possibility that interference effects would differ across experiments only because of such latency shifts. All variables were tested within subjects and within items.

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[3] We thank an anonymous reviewer for bringing this possibility to our attention.

[4] Because the spatial orientation of the object pairs was systematically varied across trials (see below), each individual object appeared equally often on the left side (to be mentioned in the first noun phrase) and on the right side (to be mentioned in the second noun phrase). In half of the trials with left or right object position, distractors were related (or unrelated) to that object. We decided to embed objects into two different pairs (and additionally to vary spatial position) in order to increase the stimulus variability and to reduce the probability that subjects would strongly resort to episodic memory representations of previously produced sentences, when repeatedly viewing a given object.

SOA was blocked, with the sequence of the SOA blocks being counterbalanced across subjects using a Latin square procedure. Furthermore, the sequence of the trials resulting from a crossing of the factors relatedness and noun position was also controlled using a Latin square procedure. This resulted in 24 experimental lists, in which, across different lists, each distractor condition appeared equally often at each repetition level of a given item in each SOA block, with the transition probability for distractor conditions being sequentially controlled. Each of the 24 subjects in Experiment 1a received one of the 24 experimental lists, and the same held for the 24 subjects in Experiment 1b. For each SOA block, the trials were pseudorandomized according to the following general criteria: (a) repetitions of an object on the left side or on the right side were separated by at least five intervening trials; (b) there were no more than three consecutive trials with the same distractor condition; (c) there were no more than four consecutive trials with the same color; (d) there were no more than four consecutive trials with the same size class; and (e) there were no more than four consecutive trials with the same grammatical gender of the left object (determining the utterance-initial definite article). Each block began with four warm-up items.

Procedure. Each subject was tested individually in a session lasting about 80 min. The subjects were seated in a dimly lit room separated from the experimenter by a partition wall. The visual stimuli were presented on a 19-in EIZO Flexscan S1910 TFT screen as colored line drawings (red, RGB 240 0 0; green, RGB 20 220 20; or blue, RGB 0 0 240) on a light gray background (RGB 240 240 240). Viewing distance was about 80 cm.

The presentation of the visual and auditory stimuli and the online collection of the data were controlled by a computer with a Pentium processor (Intel Corporation, Santa Clara, CA). Auditory distractors were presented with Sennheiser HD280pro headphones (Sennheiser Electronics, Old Lyme, CT) at a comfortable listening volume. Speech-onset latencies were measured to the closest millisecond with a voice key connected to the computer (NESU, Nijmegen Experimental Setup Unit; a system developed at the Max Planck Institute for Psycholinguistics, Nijmegen, the Netherlands) and a Sennheiser ME 64/K6 microphone. All experimental blocks were digitally recorded with a solid state recorder (Marantz PMD670) to allow for a later off-line analysis of the verbal responses, if necessary.

A trial started with the presentation of a fixation cross in the center of the screen for 800 ms, followed by a blank screen for 200 ms. Then the display with the object pair was presented for 800 ms.[5] Auditory distractors were presented slightly before (–100 ms), simultaneously with (0 ms), or slightly after (100 ms) the onset of the display. Subjects in Experiment 1a were instructed to describe the visual displays as quickly and as accurately as possible with a simple sentence of the form “the [left object] is next to the [right object]” (e.g., “the frog is next to the mug”), and subjects in Experiment 1b were instructed to describe the display with a sentence of the form “the [color] [left object] is next to the [color] [right object]” (e.g., “the red frog is next to the red mug”). Speech-onset latencies were measured during 3,000 ms from the onset of the target display. A whole trial lasted 6,000 ms.

The actual experiment consisted of three parts: a study phase, a practice phase, and the main session. During the study phase, subjects studied a written instruction that emphasized both the speed and the accuracy of their responses. The subjects also received a booklet showing all experimental pictures. The intended object name was printed next to each picture. The subjects were instructed to use these names only. Then two practice blocks were administered, in each of which all experimental and practice objects were presented once in isolation. Subjects named theses pictures with a bare noun. The experimenter monitored whether the intended target names were used and corrected the subjects if necessary. In the next two practice blocks with 32 trials each, colored double object displays composed of practice objects were presented, and the subjects described them with a sentence of the instructed form. Auditory distractors were presented only in the second of these practice blocks and with the same SOA the subject would receive in her or his first experimental block. Then, the main session started with the first of three SOA blocks. There were short breaks between these SOA blocks as well as in the middle of each SOA block.

Results and Discussion

Observations were coded as erroneous and discarded from the reaction time analyses whenever any of the following conditions held: (a) a picture had been named with a word other than the expected name; (b) an incorrect determiner was used; (c) a wrong color adjective was used (applies only to Experiment 1b); (d) an utterance was repaired; (e) a disfluency occurred; (f) a nonspeech sound preceded the target utterance, triggering the voice key; or (g) a speech-onset latency exceeded 3,000 ms.

Observations deviating from a subject’s and an item’s mean by more than two *SD*s were considered as outliers and were discarded from the reaction time analyses, as were malfunctions of the voice key. For the latter cases, however, no error was coded. According to these criteria, 10.2% of the trials (939 observations) in Experiment 1a were marked as erroneous and 2.0% of the trials (183 observations) were marked as outliers or malfunctions. In Experiment 1b, 18.0% of the trials (1,660 observations) were marked as erroneous and 1.8% of the trials (163 observations) were marked as outliers or malfunctions.

Averaged reaction times and error rates for each experiment were submitted to analyses of variance (ANOVAs). Statistical analyses involved the fixed variables relatedness (semantically related vs. unrelated), noun position (position 1 vs. 2), and SOA (–100 ms, 0 ms, 100 ms). Two complementary analyses were computed, one treating subjects and one treating items as a random variable (Clark, 1973). Table 1 displays mean reaction times and error rates for Experiments 1a and 1b, broken down by experiment, SOA, noun position, and relatedness.

Experiment 1a: Simple sentences. In the analysis of naming latencies, there was a trend toward longer naming latencies at SOA 0 ms, but this effect of SOA was not reliable in the subject analysis, $F_1(2, 46) = 1.24$, $p = .30$, $MSE = 6{,}214.87$; $F_2(2, 62) = 10.20$, $p < .001$, $MSE = 1{,}069.28$. Semantically related distractors interfered with the naming response, yielding a significant effect of relatedness, $F_1(1, 23) = 13.38$, $p < .01$, $MSE = 1{,}692.82$; F_2(1,

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[5] In all experiments, the duration of the stimulus display was deliberately kept rather short. There is some unpublished evidence that with a long stimulus presentation time perceptual and conceptual processing of the depicted objects may proceed in a more sequential manner. We thank Antje Meyer for this hint.

Table 1
Mean Naming Latencies (in Ms) and Errors Rates (in %) From Experiments 1a and 1b by SOA, Relatedness, and Noun Position

		Experiment 1a (simple sentence)				Experiment 1b (complex sentence)			
		Noun position 1		Noun position 2		Noun position 1		Noun position 2	
SOA	Relatedness	ms	%	ms	%	ms	%	ms	%
−100 ms	Related	759 (24)	10.8 (1.4)	770 (29)	11.5 (1.7)	955 (34)	17.8 (2.7)	897 (36)	19.9 (2.6)
	Unrelated	741 (26)	9.4 (1.9)	751 (25)	10.0 (1.9)	885 (33)	17.1 (2.3)	881 (33)	16.9 (2.3)
	Difference	18 (10)	1.4 (1.7)	19 (8)	1.4 (1.6)	70 (13)	0.8 (2.4)	16 (10)	3.0 (1.7)
0 ms	Related	780 (26)	9.2 (1.7)	782 (30)	12.5 (1.4)	992 (39)	20.6 (2.4)	937 (40)	18.2 (1.6)
	Unrelated	758 (26)	9.9 (1.7)	769 (28)	11.1 (1.8)	916 (34)	16.7 (1.6)	920 (36)	18.9 (2.3)
	Difference	22 (6)	−0.7 (1.5)	12 (8)	1.4 (1.6)	75 (17)	3.9 (2.0)	17 (15)	−0.7 (1.6)
100 ms	Related	774 (31)	11.2 (1.5)	761 (31)	10.4 (1.3)	1,010 (43)	19.7 (2.0)	973 (46)	18.2 (2.1)
	Unrelated	749 (31)	8.7 (1.2)	751 (29)	7.6 (1.6)	927 (36)	16.3 (1.4)	944 (40)	15.9 (1.9)
	Difference	25 (8)	2.5 (1.3)	10 (8)	2.9 (1.6)	82 (18)	3.4 (2.3)	29 (11)	2.3 (1.5)
Average	Related	770 (26)	10.4 (1.2)	771 (29)	11.5 (1.1)	984 (37)	19.4 (1.8)	936 (40)	18.8 (1.5)
	Unrelated	750 (27)	9.3 (1.2)	757 (26)	9.5 (1.4)	909 (33)	16.7 (1.5)	915 (35)	17.2 (1.6)
	Difference	21 (5)	1.1 (0.8)	14 (6)	1.9 (1.0)	75 (13)	2.7 (1.3)	21 (10)	1.6 (1.0)

Note. Positive difference scores reflect interference. Standard errors are given in parentheses. SOA = stimulus onset asynchrony.

31) = 17.43, $p < .001$, $MSE = 2{,}184.51$. There was no interaction of position and relatedness, $F_1(1, 23) = 1.82$, $p = .191$, $MSE = 674.54$; $F_2 < 1$, although descriptively the interference effect was somewhat larger for noun position 1 than for noun position 2 (21 ms vs. 14 ms).[6] The interaction of position, relatedness, and SOA was not significant either (Fs < 1). The interaction of SOA and position was significant, although only at a trend level in the subject analysis, $F_1(2, 46) = 2.64$, $p = .08$, $MSE = 632.26$; $F_2(2, 62) = 3.98$, $p < .05$, $MSE = 723.43$, reflecting a trend for faster responses for trials with distractors related to noun position 2 than to noun position 1 at SOA 100 ms, in contrast to the pattern at the other SOAs. No other effects were significant in the analysis of naming latencies. The analysis of error rates revealed an effect of relatedness at the trend level only, with more errors occurring with semantically related distractors (10.9% vs. 9.4%), $F_1(1, 23) = 4.18$, $p = .05$, $MSE = 3.96$; $F_2(1, 31) = 3.95$, $p = .06$, $MSE = 3.14$.

Experiment 1b: Complex sentences. Naming latencies increased from SOA –100 ms to SOA 100 ms, yielding a significant effect of SOA, $F_1(2, 46) = 10.20$, $p < .001$, $MSE = 8{,}325.50$; $F_2(2, 62) = 60.20$, $p < .001$, $MSE = 1{,}936.17$. There was also a significant main effect of noun position, with distractors related to position 1 yielding longer naming latencies, $F_1(1, 23) = 5.36$, $p < .05$, $MSE = 6{,}518.54$; $F_2(1, 31) = 6.56$, $p < .05$, $MSE = 9{,}820.19$. Semantically related distractors interfered with the naming response, yielding a significant effect of relatedness, $F_1(1, 23) = 26.75$, $p < .001$, $MSE = 6{,}297.64$; $F_2(1, 31) = 33.48$, $p < .001$, $MSE = 6{,}834.69$. In contrast to Experiment 1a, there was also a reliable interaction of noun position and relatedness (75 ms vs. 21 ms interference effect for positions 1 and 2, respectively), $F_1(1, 23) = 16.15$, $p < .01$, $MSE = 3{,}397.48$; $F_2(1, 31) = 24.05$, $p < .001$, $MSE = 3{,}692.42$. Subsequently computed t tests revealed that the effect of relatedness was significant for noun position 1 as well as for noun position 2: $t_1(23) = 5.84$, $p < .001$; $t_2(31) = 6.69$, $p < .001$, for noun position 1; $t_1(23) = 2.18$, $p < .05$; $t_2(31) = 2.10$, $p < .05$, for noun position 2. There was no significant interaction of noun position, relatedness, and SOA (Fs < 1). In the analysis of error rates, there was only an effect of relatedness with more errors appearing with related than with unrelated distractors (19.1% vs. 16.9%). However, in the item analysis this effect was significant only at a trend level, $F_1(1, 23) = 6.19$, $p < .05$, $MSE = 5.38$; $F_2(1, 31) = 3.48$, $p = .07$, $MSE = 7.18$.

Experiment 1a replicated the result from Meyer (1996, Experiment 2). With sentences of the form "the [left object] is next to the [right object]," there was a significant interference effect for nouns appearing at position 1 and for nouns appearing at position 2. Moreover, also in line with Meyer's study, the size of the effect did not differ significantly for the two positions. This pattern suggests that for simple sentences both noun lemmas were selected before speech onset. Although there is no syntactic necessity for selecting the lemma of the noun appearing in position 2 in order to start articulating the sentence, subjects evidently did so (see also Levelt & Meyer, 2000). When subjects produced more complex utterances (by including color information, Experiment 1b), the interference effect was enhanced. However, unlike in Experiment 1a, the interference effect was much larger for noun position 1 than for noun position 2. This difference between Experiments 1a and 1b was confirmed in a joint analysis that showed a significant interaction of position, relatedness, and experiment, $F_1(1, 46) = 9.75$, $p < .01$, $MSE = 2{,}036.01$; $F_2(1, 31) = 19.84$, $p < .001$, $MSE = 1{,}689.73$.

There are two possible explanations for this pattern of results. According to one account, the overall size of the interference effects in Experiment 1b is enhanced due to the increased load for planning the more complex noun phrases. Such enhancement of

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[6] We replicated Experiment 1a with a new subject sample ($N = 16$) and testing SOAs of –100 ms and 100 ms, while additionally measuring eye movements (which required some adjustment to the trial scheme). In this replication, interference effects of 34 ms for noun position 1 and 31 ms for noun position 2 were obtained, yielding a significant effect of relatedness: $F_1(1, 15) = 32.82$, $p < .001$, $MSE = 1{,}028.81$; $F_2(1, 31) = 26.58$, $p < .001$, $MSE = 2{,}878.62$. Again, there was no interaction of relatedness and position (Fs < 1). Thus, this replication once more demonstrates that semantic interference of similar size is obtained for the two noun positions in simple sentences.

interference as a function of cognitive load has been previously reported by Lavie and colleagues (e.g., Lavie, Hirst, de Fockert, & Viding, 2004).[7] At the same time, the increased load reduces the advance planning span, such that the first noun phrase is included in the advance planning scope on all trials (contributing to a rather large interference effect) and the second noun phrase is included in the advance planning scope on only a relatively small proportion of the trials. The mixture of trials in which it not had been included (not contributing to the overall interference effect) and trials in which it had (contributing to the overall interference effect) then resulted in a diminished overall effect for the second noun.

According to a second account, however, the pattern for Experiment 1b might not be due to an adjusted advance planning scope but simply to a shift in speech onset latencies. On average, the overall reaction times for the complex utterances in Experiment 1b were about 170 ms longer than those for the simple utterances in Experiment 1a. Because the same SOA range (–100 ms, 0 ms, and 100 ms) was used for both utterance types, one could argue that, for complex utterances, the activation of the distractor that is semantically related (or unrelated) to the second noun had already begun to dissipate by the time the second noun phrase was being planned, such that it was less potent. There are two reasons speaking against this interpretation. First, the interference effects in Experiments 1a and 1b were present throughout the whole SOA range, and the SOA manipulation used (spanning 200 ms) was larger than the actual latency shift (of about 170 ms). Second, a more detailed analysis of the data disconfirms predictions that should hold if this interpretation were correct. In particular, if the assumption of dissipating distractor activation in the case of complex utterances were correct, one would predict that the semantic interference effect for the second noun in complex utterances is primarily carried by fast speakers (i.e., speakers with short speech onset latencies), for whom distractor activation should have less of a chance to dissipate before the second noun phrase is being planned. By contrast, the effect should be diminished or even absent for slow speakers, as the distractor activation has a larger chance to dissipate before the second noun phrase is being planned.

To test this prediction, we divided the 24 subjects from Experiment 1b (complex utterances) into a slow and a fast group, based on a median split of their average naming latencies in the unrelated distractor conditions collapsed over SOAs (slow group: $M = 1{,}045$ ms, $SD = 108$; fast group: $M = 779$ ms, $SD = 93$). For the first noun, the semantic interference effect was somewhat smaller for the slow group than for the fast group (66 ms and 86 ms, respectively, averaged across SOAs). For the second noun, by contrast, the semantic interference effect was almost twice as large for the slow group as for the fast group (27 ms and 14 ms, respectively).[8] This descriptive interference pattern is precisely the reverse of what one would have expected if the overall smaller interference effect for the second noun (as compared to the first noun) in complex utterances is due to a dissipation of distractor activation with longer utterance onset latencies. Just to the contrary, the median split analyses suggest that fast speakers are more likely to start articulation after having planned only the first noun phrase, while slow speakers are more likely to start articulation only after having planned both noun phrases. However, we have to keep in mind that in both groups, the semantic interference effect for the second noun was smaller than that for the first noun. This suggests that in both groups, complex utterances were planned in an incremental way on a proportion of trials, but this proportion of trials with incremental planning appears to be smaller for the slow group than for the fast group.

We also explored whether this differential interference pattern as a function of overall speed extends to the simple utterances tested in Experiment 1a. For the first noun, the semantic interference effect averaged across SOAs was about equally large for the slow group (mean reaction time in the unrelated condition = 854 ms, 18 ms interference) and the fast group (mean reaction time in the unrelated condition = 652 ms, 26 ms interference; Fs < 1 for the interaction of group and relatedness). For the second noun, by contrast, the semantic interference effect was present in the slow group but absent in the fast group (24 ms and 3 ms, respectively), and this descriptive pattern was confirmed in the statistical analyses, although at a trend level only, $F_1(1, 22) = 3.26$, $p = .09$, $MSE = 1{,}185.43$; $F_2(1, 31) = 6.32$, $p < .05$, $MSE = 1{,}862.05$, for the interaction of group and relatedness. Thus, the overall pattern emerging from these analyses resembles the one we had observed for complex utterances.

There is one other potential caveat regarding the interpretation of differences in the size of the interference effect for the first noun in the experiments reported thus far. For complex sentences, we have seen a fairly large interference effect for the first noun (as compared to the corresponding effect in simple sentences) and a small interference effect for the second noun. Above, we attributed the increase in the size of the effect for the first noun in complex utterances to the additional load that goes along with these utterances. We further assumed that at the same time the additional load reduced the advance planning scope and thus reduced or eliminated the effect for the second noun. However, one could also consider a different reason for the boost of the first noun effects in complex utterances. In our experiments, complex utterances differed from simple utterances in that the color of the objects had to be mentioned in the target sentence. As the two objects on a given trial were always presented in the same color, one could speculate that only the planning of the first noun phrase became more difficult (due to conceptualization and lexicalization of the color information) and that this was not the case for the planning of the second noun phrase (in which the color adjective already retrieved could have been reused). As a consequence, subjects could have

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[7] In their experiments, subjects had to remember either one digit (low working memory load) or six digits (high working memory load) while performing a flanker task, in which a letter had to be classified while an accompanying distractor letter of either the same or the opposite response class was ignored. With low working memory load, a congruency effect (difference between the incongruent and the congruent distractor condition) of 140 ms was observed, and with high working memory load a congruency effect of 193 ms was observed. These results indicate that cognitive load boosts interference effects. This is contrast to the effect of perceptual load, which tends to reduce interference effects (cf. Lavie et al., 2004).

[8] Despite these descriptive trends, the statistical analyses revealed no significant interactions of relatedness and group: $F_1 < 1$; $F_2(1, 31) = 2.01$, $p = .17$, $MSE = 5{,}225.70$, for the first noun; both Fs < 1.3, for the second noun. Note also that with respect to overall naming latencies the fast group in Experiment 1b is quite comparable to the subject sample from Experiment 1a ($M = 753$ ms, $SD = 130$ ms).

focused on the planning of the first noun phrase in complex utterances. This, in turn, might have made the first noun phrase more susceptible than the second noun phrase to interference and at the same time might have reduced or eliminated the effect for the second noun phrase. To test this possibility, we conducted Experiment 1c.

Experiment 1c

Experiment 1c was similar to Experiment 1b in that it involved the production of the complex sentences. However, in contrast to Experiment 1b the objects were depicted in different colors (e.g., "the red frog is next to the blue mug"), and all other procedural details were kept the same as in Experiment 1b. If the alternative account sketched above is correct, one would expect the interference effect for the second noun to be increased and, possibly, that for the first noun to be reduced, when compared to the effects in Experiment 1b.

Method

Subjects. Twenty-four subjects were tested. Application of the exclusion and replacement criteria (see Experiments 1a and 1b) led to the replacement of one subject. However, because the complex utterances with two different color adjectives led to a proportion of utterances with errors and/or disfluencies much higher than that for the complex utterances in Experiment 1b, we set the absolute maximum number of errors with which a subject was included in the analyses to 50% (as opposed to 33% in the other experiments with complex sentences).

Materials. The same materials as those in Experiments 1a and 1b were used, with the difference that in this experiment the objects were of different colors. We changed the color of the objects so that the color of the object to which the related (or unrelated) distractors were assigned was the same as in Experiment 1b and each possible color combination appeared about equally often.

Design. The design was identical to the one used in Experiment 1b.

Procedure. The procedure was the same as in Experiment 1b.

Results and Discussion

Observations were coded as erroneous and discarded from the reaction time analyses according to the same criteria as in Experiment 1b. In all, 25.7% of the trials (2,372 observations) were marked as erroneous and 1.7% of the trials (151 observations) were marked as outliers or malfunctions.

Averaged reaction times and error rates were submitted to ANOVAs. Statistical analyses involved the variables relatedness (semantically related vs. unrelated), noun position (noun position 1 vs. 2), and SOA (–100 ms, 0 ms, 100 ms) as within-subject and within-item factors. Table 2 displays mean naming latencies and error rates, broken down by SOA, noun position, and relatedness.

Naming latencies increased from SOA –100 ms to SOA 100 ms, yielding a significant effect of SOA, $F_1(2, 46) = 4.35$, $p < .05$, $MSE = 10{,}499.69$; $F_2(2, 62) = 34.16$, $p < .001$, $MSE = 1{,}723.99$. Semantically related distractors interfered with the naming response, yielding a significant effect of relatedness, $F_1(1, 23) = 31.65$, $p < .001$, $MSE = 3{,}865.42$; $F_2(1, 31) = 15.85$, $p < .001$, $MSE = 8{,}002.18$. There was also an effect of position, with naming latencies being longer with distractors related or unrelated to noun position 1, $F_1(1, 23) = 5.39$, $p < .05$, $MSE = 7{,}109.82$; $F_2(2, 31) = 7.41$, $p < .05$, $MSE = 14{,}415.75$. The interaction of position and relatedness was highly significant (70 ms vs. 11 ms interference effect for noun position 1 and noun position 2, respectively), $F_1(1, 23) = 29.26$, $p < .001$, $MSE = 2{,}291.47$; $F_2(1, 31) = 18.78$, $p < .001$, $MSE = 5{,}895.60$. Subsequently computed t tests revealed that the effect of relatedness was significant for noun position 1 only: $t_1(23) = 6.02$, $p < .001$; $t_2(31) = 7.40$, $p <$

Table 2
Mean Naming Latencies (in Ms) and Errors Rates (in %) From Experiment 1c by SOA, Relatedness, and Noun Position

		Complex sentence			
		Noun position 1		Noun position 2	
SOA	Relatedness	ms	%	ms	%
−100 ms	Related	989 (36)	25.0 (2.9)	926 (38)	25.5 (3.7)
	Unrelated	912 (35)	26.4 (2.9)	909 (35)	23.8 (2.9)
	Difference	78 (18)	−1.4 (1.8)	17 (12)	1.7 (2.2)
0 ms	Related	1,013 (35)	27.6 (3.4)	947 (35)	29.0 (3.8)
	Unrelated	940 (32)	24.5 (2.7)	937 (33)	23.2 (3.8)
	Difference	73 (14)	3.1 (2.0)	10 (13)	5.9 (1.8)
100 ms	Related	1,011 (39)	31.1 (2.7)	979 (46)	25.8 (3.3)
	Unrelated	946 (41)	24.3 (2.9)	974 (47)	22.5 (2.7)
	Difference	65 (16)	6.8 (2.0)	5 (14)	3.3 (2.0)
Average	Related	1,003 (35)	27.9 (2.6)	950 (38)	26.8 (3.1)
	Unrelated	933 (35)	25.1 (2.4)	939 (36)	23.2 (2.5)
	Difference	70 (12)	2.8 (1.2)	11 (7)	3.6 (1.1)

Note. Positive difference scores reflect interference. Standard errors are given in parentheses. SOA = stimulus onset asynchrony.

.001, for noun position 1; $t_1(23) = 1.56$, $p = .13$; $t_2(31) = 0.26$, $p = .79$, for noun position 2. The interaction of SOA and position was significant, $F_1(2, 46) = 4.35$, $p < .05$, $MSE = 1{,}834.02$; $F_2(2, 62) = 5.31$, $p < .01$, $MSE = 2{,}221.43$. In the analysis of error rates, there was an effect of relatedness, with more errors appearing with related than with unrelated distractors, $F_1(1, 23) = 13.93$, $p < .01$, $MSE = 5.46$; $F_2(1, 31) = 10.03$, $p < .01$, $MSE = 5.69$. The interaction of SOA and relatedness was also significant, $F_1(2, 46) = 3.36$, $p < .05$, $MSE = 5.26$; $F_2(2, 62) = 4.68$, $p < .05$, $MSE = 2.83$, reflecting the fact that a relatedness effect was present only at SOAs 0 ms and 100 ms (ps $< .01$) and not at SOA –100 ms (ps $> .9$).

Collapsed over SOAs, there was an interference effect of 70 ms for the first noun (as compared to 75 ms in Experiment 1b) and an interference effect of 11 ms for the second noun (as compared to 21 ms in Experiment 1b). This pattern of results did not differ statistically across experiments: Fs < 1 for the interaction of experiment, relatedness, and position; Fs < 1 for the interaction of experiment and relatedness, when restricting the analyses to the first noun; $F_1 < 1$, $F_2(1, 31) = 3.67$, $p = .07$, $MSE = 1{,}679.94$, for the interaction of experiment and relatedness, when restricting the analyses to the second noun. If anything, the interference effect for the second noun was descriptively smaller in Experiment 1c, in contrast to what the alternative account had predicted. Moreover, a division of the subjects in Experiment 1c into a group of fast speakers and a group of slow speakers (fast group: $M = 789$ ms, $SD = 36$ ms; slow group: $M = 1{,}084$ ms, $SD = 117$ ms) yielded a pattern comparable to that in Experiment 1b. The interference effects for the first noun were very similar for the fast and the slow group (77 ms and 63 ms, respectively, as compared to 86 ms and 66 ms in Experiment 1b), and the interference effect for the second noun was smaller for the fast group than for the slow group (5 ms and 18 ms, respectively, as compared to 14 ms and 27 ms in Experiment 1b). Thus, we can conclude that the latency pattern observed for complex utterances is independent of whether the two objects have the same color or different colors and thus that the increased interference effect cannot be considered an artifact of our experimental procedure.

Against the background of these results, Experiment 2 tested whether the scope of grammatical advance planning is affected by introducing additional cognitive load. Cognitive load was introduced by a conceptual decision task (natural-size decision of the depicted objects) whose outcome determined the utterance format to be used (simple vs. complex sentence). If cognitive load narrows down the scope of advance planning, the interference effects for the second noun should be attenuated or even eliminated. If, however, cognitive load increases the scope of advance planning (see above), the interference effects for the second noun should become larger, in particular for complex sentences. Furthermore, Experiment 2 also allowed us to test whether the differential interference patterns for fast and slow speakers that we had observed in Experiment 1 persist with increased cognitive load.

Because of the parallel pattern of results in Experiments 1b and 1c, and because of the much higher number of errors in Experiment 1c (and thus a considerable loss of utterances for which naming latencies can be analyzed), we used the same procedure as in Experiment 1b (same color of both objects) for the complex utterances in Experiment 2.

Experiment 2

Experiment 2 was similar to Experiments 1a and 1b in that it involved the production of the same simple and complex sentences. However, in contrast to Experiments 1a and 1b, in which utterance format was kept constant within subjects, subjects now had to switch between simple and complex utterances on the basis of a conceptual decision task concerning the natural size of the depicted objects. The outcome of the decision process determined which utterance format had to be used (i.e., simple sentence for objects with large natural size and complex sentences for objects with small natural size, or vice versa, depending on the particular subject group). Thus, Experiment 2 involved a switch in utterance formats (simple vs. complex sentences), on the basis of a conceptual decision task, and thus an increase of cognitive load.

Method

Subjects. Forty-eight subjects were tested. Application of the exclusion and replacement criteria (see Experiments 1a and 1b) led to the substitution of eight subjects. Half of the subjects produced simple sentences, if the objects of a pair were of large natural size (compared to a given standard), and complex sentences, if the objects of a pair were of small natural size. For the other half of the subjects, the assignment of utterance format to natural size was reversed.

Materials. The same materials as in Experiment 1 were used. A box with the size of 26.5 × 18.0 × 12.5 cm (width × height × depth) served as the standard for the natural size decision task. It was presented to the subjects while they studied the instructions for the training block in which subjects started to produce sentences.

Design. The design was identical to the one used in Experiment 1 except for the additional variable utterance format that was tested within subjects.

Procedure. The procedure was the same as in Experiment 1, except that the format of the to-be-produced sentence was now contingent on the natural size of the depicted objects. Half of the subjects were instructed to produce a simple sentence if the natural size of the depicted objects was larger than the standard (box) and a complex sentence if it was smaller. For the other half of subjects, the assignment of utterance formats to the outcome of the natural size decision was reversed. This additional feature of the task was introduced during the training phase, when subjects started to produce sentences (from the third practice block onward).

Results and Discussion

Observations were coded as erroneous and discarded from the reaction time analyses according to the same criteria as in Experiment 1. In addition, an error was coded when subjects had used the wrong utterance format; this error type occurred in 1.3% of the trials (232 observations). Overall, 15.3% of the trials (2,824 observations) were coded as erroneous and 2.3% of the trials (419 observations) were marked as outliers or malfunctions. For the simple sentence format, 10.6% of the trials (974 observations) were marked as erroneous and 2.6% of the trials (238 observations) were marked as outliers or malfunctions of the voice key. For the complex sentence format, 20.1% of the trials (1,850 observations) were marked as erroneous and 1.9% of the trials (181 observations) were marked as outliers or malfunctions.

Averaged reaction times and error rates were submitted to ANOVAs for simple and complex utterances separately. Statistical analyses involved the variables relatedness (semantically related vs. unrelated), noun position (noun position 1 vs. 2), and SOA (–100 ms, 0 ms, 100 ms) as within-subject and within-item factors. Table 3 displays mean naming latencies and error rates for Experiment 2, broken down by utterance format, SOA, noun position, and relatedness.

Simple sentences. Naming latencies increased from SOA –100 ms to SOA 100 ms, yielding a significant effect of SOA, $F_1(2, 94) = 15.83$, $p < .001$, $MSE = 15{,}263.02$; $F_2(2, 62) = 77.49$, $p < .001$, $MSE = 2{,}164.39$. Semantically related distractors interfered with the naming response, yielding a significant effect of relatedness, $F_1(1, 47) = 19.36$, $p < .001$, $MSE = 3{,}233.72$; $F_2(1, 31) = 10.44$, $p < .01$, $MSE = 3{,}861.94$. There was also an effect of position, with naming latencies being longer with distractors related or unrelated to noun position 1, although the effect was significant only at a trend level in the subject analysis and was not replicated in the item analysis, $F_1(1, 47) = 3.91$, $p = .05$, $MSE = 2{,}659.69$; $F_2(1, 31) = 1.36$, $p = .25$, $MSE = 5{,}577.82$. The interaction of position and relatedness was highly significant (44-ms interference effect for noun position 1 and a 3-ms difference in the opposite direction for noun position 2), $F_1(1, 23) = 35.15$, $p < .001$, $MSE = 2{,}356.62$; $F_2(1, 31) = 27.46$, $p < .001$, $MSE = 2{,}118.75$. Subsequently computed *t* tests revealed that the effect of relatedness was significant for noun position 1 only: $t_1(47) = 6.06$, $p < .001$; $t_2(31) = 4.90$, $p < .001$, for noun position 1; $t_1(47) = 0.64$, $p = .53$; $t_2(31) = 0.76$, $p = .45$, for noun position 2. The interaction of SOA and relatedness was significant, although only at a trend level in the subject analysis, $F_1(2, 94) = 2.37$, $p = .10$, $MSE = 1{,}816.05$; $F_2(2, 62) = 3.32$, $p < .05$, $MSE = 1{,}257.37$. No other effects were significant in the analysis of naming latencies. In the analysis of error rates, there were no significant effects.

Complex sentences. Naming latencies increased from SOA –100 ms to SOA 100 ms, yielding a significant effect of SOA, $F_1(2, 94) = 15.19$, $p < .001$, $MSE = 16{,}385.72$; $F_2(2, 62) = 78.72$, $p < .001$, $MSE = 2{,}117.43$. Semantically related distractors interfered with the naming response, yielding a highly significant effect of relatedness, $F_1(1, 47) = 38.83$, $p < .001$, $MSE = 5{,}258.42$; $F_2(1, 31) = 26.76$, $p < .001$, $MSE = 5{,}151.69$. There was also an effect of position, with naming latencies being longer with distractors related or unrelated to noun position 1, $F_1(1, 47) = 29.34$, $p < .001$, $MSE = 4{,}329.58$; $F_2(2, 62) = 6.87$, $p < .05$, $MSE = 12{,}977.95$. Position and relatedness interacted (72 ms vs. 4 ms inference for noun positions 1 and 2, respectively), $F_1(1, 47) = 40.49$, $p < .001$, $MSE = 4{,}356.02$; $F_2(1, 31) = 22.37$, $p < .001$, $MSE = 5{,}552.78$. Subsequently computed *t* tests revealed that the effect of relatedness was significant for noun position 1 only: $t_1(47) = 8.28$, $p < .001$; $t_2(31) = 6.02$, $p < .001$, for noun position 1; $t_1(47) = 0.46$, $p = .65$; $t_2(31) = 0.16$, $p = .87$, for noun position 2. The interaction of SOA and position was also significant, $F_1(2, 94) = 3.36$, $p < .05$, $MSE = 3{,}229.45$; $F_2(2, 62) = 3.67$, $p < .05$, $MSE = 2{,}270.60$, reflecting the fact that at SOA –100 ms, in contrast to the later SOAs, responses were faster in trials with distractors related or unrelated to noun position 2 than in trials with distractors related or unrelated to noun position 1. Finally, the interaction of SOA, position, and relatedness was significant at a trend level in the subject analysis, but this trend could not be confirmed in the item analysis, $F_1(2, 94) = 2.92$, $p = .06$, $MSE = 2{,}216.79$; $F_2(2, 62) = 1.01$, $p = .37$, $MSE = 1{,}873.73$.

The analysis of error rates revealed slightly higher error rates for distractors related or unrelated to noun position 1 as compared to noun position 2 (21.0% vs. 19.2%), but this effect was significant only at a trend level, $F_1(1, 47) = 3.12$, $p = .08$; $MSE = 3.74$; $F_2(1, 31) = 2.93$, $p = .10$, $MSE = 5.98$. Semantically related distractors induced more errors than did unrelated distractors, yielding a significant effect of relatedness (22.7% vs. 17.4%), $F_1(1, 47) = 38.18$, $p < .001$, $MSE = 2.66$; $F_2(1, 31) = 42.79$, $p < .001$, $MSE = 3.56$. The relatedness effect was similarly sized for noun

Table 3
Mean Naming Latencies (in Ms) and Errors Rates (in %) From Experiments 2 by Utterance Format, SOA, Relatedness, and Noun Position

		Simple sentence				Complex sentence			
		Noun position 1		Noun position 2		Noun position 1		Noun position 2	
SOA	Relatedness	ms	%	ms	%	ms	%	ms	%
−100 ms	Related	833 (18)	11.8 (1.6)	807 (17)	9.2 (1.1)	954 (25)	24.0 (2.4)	871 (19)	21.0 (1.9)
	Unrelated	792 (16)	9.2 (1.4)	794 (16)	9.9 (1.3)	872 (20)	17.3 (1.8)	859 (19)	17.1 (1.6)
	Difference	41 (10)	2.6 (1.6)	13 (6)	−0.7 (1.3)	83 (12)	6.6 (2.4)	12 (9)	3.9 (1.8)
0 ms	Related	881 (22)	12.0 (1.3)	846 (19)	11.7 (1.5)	990 (29)	22.5 (2.0)	921 (23)	21.1 (2.1)
	Unrelated	842 (19)	9.5 (1.4)	865 (21)	10.5 (1.4)	905 (22)	20.1 (2.1)	939 (24)	16.3 (1.5)
	Difference	39 (13)	2.5 (1.3)	−19 (9)	1.2 (1.4)	85 (13)	2.5 (1.7)	−8 (13)	4.8 (2.0)
100 ms	Related	906 (22)	10.4 (1.4)	869 (21)	11.1 (1.5)	996 (27)	24.1 (2.1)	951 (23)	23.6 (1.0)
	Unrelated	852 (19)	10.3 (1.3)	872 (22)	11.1 (1.4)	945 (23)	17.8 (1.8)	947 (25)	16.1 (1.7)
	Difference	54 (8)	0.1 (1.7)	−3 (9)	0.0 (1.1)	50 (10)	6.3 (1.8)	4 (11)	7.4 (1.9)
Average	Related	872 (18)	11.4 (1.0)	839 (17)	10.7 (1.0)	979 (25)	23.5 (1.7)	915 (20)	21.9 (1.6)
	Unrelated	827 (16)	9.7 (1.0)	843 (18)	10.5 (1.0)	907 (20)	18.4 (1.4)	911 (21)	16.5 (1.2)
	Difference	44 (7)	1.7 (1.0)	−3 (5)	0.2 (0.7)	72 (9)	5.1 (1.3)	4 (8)	5.4 (1.2)

Note. Positive difference scores reflect interference. Standard errors are given in parentheses. SOA = stimulus onset asynchrony.

positions 1 and 2 (5.1% vs. 5.4%), and the interaction of relatedness and position was far from being significant (*F*s < 1).

Before we discuss the implications of these data in detail, a note on overall latencies is in place. When the latencies for the different sentence formats in Experiments 1 and 2 are compared, there is hardly any difference for complex utterances (909 ms and 912 ms, respectively, for unrelated conditions only). Latencies for simple utterances were somewhat longer in Experiment 2 than in Experiment 1a (835 ms and 753 ms, respectively) but were still faster than latencies for complex utterances. These comparisons again confirm that any differences in the interference patterns cannot be due to a shift in onset latencies. Rather, the absence of any interference effects in the naming latencies for noun position 2 in Experiment 2 suggests that the additional conceptual decision task in combination with a variable utterance format was effective in reducing the scope of advance planning, such that only the noun lemma for the sentence initial phrase was selected prior to speech onset. This interpretation is also supported by the results from simple sentences. However, the finding of a significant relatedness effect in the error rates for complex utterances that was similarly sized for noun positions 1 and 2 is at odds with this view. In contrast to the other data mentioned, this pattern seems to indicate that the noun lemma for noun position 2 was processed before speech onset. Such a conclusion, however, would be puzzling, given that the effect was obtained for the more demanding complex sentence format only, and not—as logically to be expected—for the less demanding simple sentence format as well.

But there is also a different interpretation of the observed difference in the pattern of reaction times and error rates for complex utterances. An increase in utterance onset latencies obviously reflects extended planning processes before utterance onset. An increase in errors, by contrast, may have different sources. It may but need not indicate problems occurring before utterance onset. Alternatively, it could also reflect problems occurring after utterance onset (i.e., problems that arise when articulation has already started). This latter possibility is presumably more likely to occur with complex (i.e., longer) utterances. The corresponding errors, then, would not be informative with respect to the state of affairs prior to speech onset, in particular the scope of advance planning, but would rather inform us about problems that have occurred further downstream. To explore this possibility, we performed a more detailed analysis of the errors obtained for complex utterances. For each error, we determined whether it had occurred (a) prior to speech onset proper (lip smacks and filled pauses), (b) within the first noun phrase, or (c) after the first noun phrase. The results of this analysis are depicted in Figure 1.

As can be seen, distractors semantically related to the first noun led to interference while subjects produced the first noun phrase but not thereafter. By contrast, distractors related to the second noun led to interference after subjects had completed the production of the first noun phrase but not earlier. This descriptive pattern was substantiated in the statistical analyses. There was a significant interaction of error position, noun position, and relatedness, $F_1(2, 94) = 23.31$, $p < .001$, $MSE = 1.21$; $F_2(2, 62) = 15.21$, $p < .001$, $MSE = 2.79$. Subsequent analyses were conducted for each error location separately. For errors occurring prior to speech onset (e.g., lip smacks or filled pauses), there was neither an effect of relatedness nor an interaction of relatedness and noun position (*F*s < 1). By contrast, this interaction was significant for errors occurring within the first noun phrase, $F_1(1, 47) = 12.71$, $p < .01$, $MSE = 2.17$; $F_2(1, 31) = 8.12$, $p < .01$, $MSE = 5.09$, and for errors occurring after the first noun phrase, $F_1(1, 47) = 29.61$, $p < .001$, $MSE = 0.98$; $F_2(1, 31) = 29.05$, $p < .001$, $MSE = 1.49$. Subsequent analyses showed that for errors occurring within the first noun phrase, there was interference from distractors related to the noun in position 1, $t_1(47) = 5.37$, $p < .001$; $t_2(31) = 4.00$, $p < .001$, but no effect from distractors related to the noun in position 2 (*t*s < 1). By contrast, for errors occurring after the first noun phrase, the pattern was reversed. There was no effect from distractors related to the noun in position 1, $t_1(47) = 1.38$, $p = .18$; $t_2(31) = 1.45$, $p = .16$, but there was interference from distractors related to the noun in position 2, $t_1(47) = 5.56$, $p < .001$; $t_2(31) = 6.70$, $p < .001$. The outcome of this analysis, then, is compatible with the view that the lemma of the noun in position 2 had not been selected prior to articulation, because there was no specific interference effect before speech onset. Rather, it was processed later on, leading to specific interference from a related distractor after articulation of the initial noun phrase had been completed. To be sure, the outcome of this detailed error analysis does not allow us to exclude with absolute certainty that the noun at position 2 had been activated at speech onset, but in the context of the naming latency pattern for the complex sentences as well as the naming latency and error rate pattern for the simple sentences (which all speak against such a possibility), the most parsimonious interpretation seems to us that it had not.

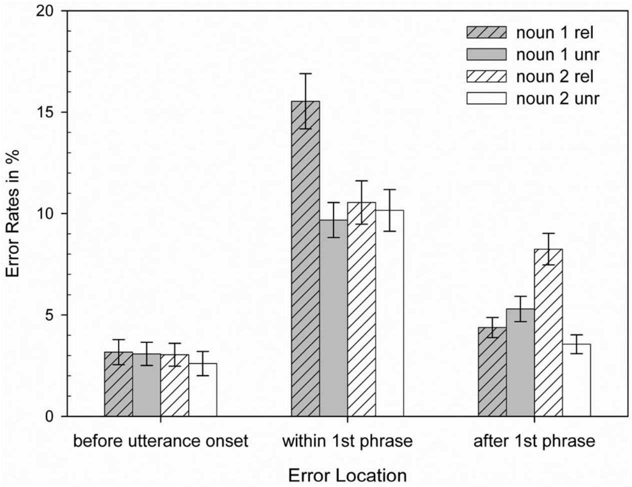

Figure 1. Mean error rates (in %) and corresponding standard errors from the complex utterances in Experiment 2 broken down by relatedness, noun position, and location at which the error occurred. rel = related; unr = unrelated.

In summary, Experiment 2, involving a conceptually driven decision about the format of the to-be-produced utterance, succeeded in eliminating the interference effects for the noun in second position, and this was the case for simple as well as for complex sentences. This was also the case when the data from slow and fast speakers were analyzed separately, as we had done for Experiment 1. For simple utterances, the interference effect for the noun in second position amounted to 2 ms for fast speakers and –9 ms for slow speakers (for the unrelated condition, $M = 749$ ms, $SD = 13$, and $M = 929$ ms, $SD = 17$, for the fast and slow speakers, respectively). For complex utterances, the corresponding interference effects were 9 ms for fast speakers and –1 ms for slow speakers (*M* = 801 ms, *SD* = 16, and *M* = 1,018 ms, *SD* = 20, for the fast and slow speakers, respectively).

The resulting overall pattern, then, shows that—as cognitive load due to increased task demands during speech planning is enhanced—the scope of advance planning is narrowed down and is restricted to the first noun phrase. This holds for fast speakers as well as for slow speakers. Put differently, it seems that under relatively low cognitive load speakers are able to make use of different planning styles, as indicated by the difference between fast and slow speakers in Experiments 1a, 1b, and 1c; under a high cognitive load, as in the present experiment, all speakers switch to an incremental planning style, with the scope of grammatical advance planning being restricted to the first noun phrase.

In the experiments presented thus far, task difficulty was manipulated either by making the utterance more complex, and thus conceptualization and formulation more demanding (Experiments 1b and 1c), or by introducing a conceptual decision task directly relating to the to-be-named objects, with the outcome of the conceptual decision task determining which utterance format had to be used (Experiment 2). Put differently, the additional cognitive load was directly related to the actual response to be produced. This procedure contrasts with classical dual-task approaches exploring the effect of cognitive load on some particular process (for a review, see Pashler & Johnston, 1998). Corresponding studies have shown that simultaneous performance of separate tasks that require independent responses leads to dual-task interference (i.e., speed and accuracy suffer relative to task performance in isolation). A number of independent secondary tasks have been used in those studies, including working memory tasks in which a memory set has to be retained in working memory as some other task is being carried out (e.g., de Fockert, Rees, Frith, & Lavie, 2001; Lavie et al., 2004; Stins, Vosse, Boomsma, & de Geus, 2004). Thus far, there are only a few approaches in the domain of speech production adopting this approach, and most of these studies focused either on discourse (Jou & Harris, 1992; Oomen & Postma, 2001) or on single word production (e.g., Belke, 2008; V. S. Ferreira & Pashler, 2002; for sentence production, see Hartsuiker & Barkhuysen, 2006; Power, 1985). In order to explore whether the effects of task demands on the scope of advance planning during sentence production, which we have thus far observed, generalize to situations in which cognitive load is increased by manipulations, which do not directly relate to the to-be-produced response, we performed one more pair of experiments using a standard dual-task approach.

Experiments 3a and 3b

In Experiments 3a and 3b, we used a standard dual-task approach to explore the effect of cognitive load on advance planning in a typical dual task situation. As in Experiment 1a, subjects produced simple sentences, but this time they had to retain a set of either five digits (in Experiment 3a) or five adjectives (in Experiment 3b) in working memory during speech planning. We chose a verbal rather than a visual working memory task because an additional visual stimulus could have interfered with the perceptual processes preceding the preparation of the verbal response. Digits and words were contrasted to explore whether the type of memory materials would have an effect. The crucial question was whether a modulation of advance planning due to increased task demands would again be observed.

Method

Subjects. Forty-eight subjects were tested, half of them in Experiment 3a (digit memory set) and half of them in Experiment 3b (adjective memory set). Use of the exclusion criteria applied in all previous experiments led to the replacement of three subjects in Experiment 3a and four subjects in Experiment 3b. Subjects were also replaced if their performance in the working memory task was at chance level (one subject in Experiment 3a and two subjects in Experiment 3b).

Materials. For the speech production task, the materials used were the same as in Experiment 1. For the additional working memory task, memory sets consisting of five digits (0–9) or five adjectives (see Appendix B) were constructed with the following constraints: (a) a digit or an adjective did not occur more than once in a given set and (b) across the whole experiment, all digits or adjectives appeared approximately equally often and were approximately equally distributed across positions within the memory sets. In addition, no ascending or descending order of more than two digits was allowed in Experiment 3a. Each digit or adjective figured about equally often as the recognition probe, balanced for positive and negative trials.

Design. The design was identical to the one used in Experiment 1a with the exception that just one SOA (–100 ms) was tested.

Procedure. The procedure was the same as in Experiment 1 with the following exceptions. A trial started with the presentation of the memory set (five digits in Experiment 3a or five adjectives in Experiment 3b) at the center of the screen for 2,500 ms, followed by a blank screen for 200 ms, a fixation cross for 800 ms, and again a blank screen for 200 ms. Then the object pair to be described with a simple sentence was presented for 800 ms. Auditory distractors were presented 100 ms before picture onset (SOA –100 ms).[9] Four seconds after picture onset, a question mark and a probe were presented. Subjects were instructed to press a button labeled *yes* (right button), if the probe was contained in the memory set, or to press a button labeled *no* (left button), if the probe was not contained in the memory set. Question mark and probe disappeared as soon as the subject had responded or after 4 s had elapsed without response. In case of wrong responses or time-outs, subjects received corresponding visual feedback (*wrong* or *time out*) for 1 s. The next trial started 300 ms later. Thus, a whole trial lasted between 8 and 13 s. Because the trials were considerably longer than in Experiment 1, short breaks were made after every 32 experimental trials (instead of 64).

Results and Discussion

In the naming task, observations were coded as erroneous and discarded from the reaction time analyses according to the same

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[9] Restriction to a single SOA was necessary because the increased trial length did not allow us to test multiple SOAs in an experimental session. The particular SOA value (–100 ms) was chosen because the results found for that SOA in Experiments 1 and 2 best resembled the overall patterns of the respective experiments.

criteria as in Experiment 1a. For Experiment 3a, 320 observations (10.4% of the trials) were marked as erroneous and 65 observations (2.1% of the trials) were marked as outliers or malfunctions. For Experiment 3b, 309 observations (10.1% of the trials) were marked as erroneous and 54 observations (1.8% of the trials) were marked as outliers or malfunctions. In the working memory task, subjects responded incorrectly in 14.2% of the trials (min = 1.6%, max = 36.7%, *SD* = 8.3%) in Experiment 3a and in 21.5% of the trials (min = 9.4%, max = 32.8%, *SD* = 7.9%) in Experiment 3b. Because it cannot be determined whether these errors arose prior to, during, or after the speech planning, naming latencies from these trials with incorrect probe responses were included in the analyses to avoid an excessive loss of data points.[10]

Averaged reaction times and error rates for each experiment were submitted to ANOVAs with the fixed variables relatedness (semantically related vs. unrelated) and noun position (position 1 vs. 2). Table 4 displays mean reaction times and error rates (not including errors in the working memory task) for Experiments 3a and 3b, broken down by experiment, noun position, and relatedness.

Experiment 3a: Digit memory set. In the analysis of naming latencies, semantically related distractors interfered with the naming response, yielding a significant effect of relatedness, $F_1(1, 23) = 39.58$, $p < .001$, $MSE = 848.91$; $F_2(1, 31) = 36.12$, $p < .001$, $MSE = 1{,}559.28$. A similar trend was present in the error rates, although the effect was just significant in the item analysis and was not significant in the subject analysis, $F_1(1, 23) = 2.69$, $p = .12$, $MSE = 3.04$; $F_2(1, 31) = 4.09$, $p = .05$, $MSE = 1.50$. Most important, there was no interaction of relatedness and noun position (Fs < 1 for naming latencies; Fs < 1.8 for error rates). The main effect of noun position was not significant either.

Experiment 3b: Adjective memory set. In the analysis of naming latencies, semantically related distractors interfered with the naming response, yielding a significant effect of relatedness, $F_1(1, 23) = 76.35$, $p < .001$, $MSE = 474.53$; $F_2(1, 31) = 13.69$, $p < .01$, $MSE = 2{,}687.52$. As in Experiment 3a, there was no interaction of relatedness and noun position, $F_1(1, 23) < 1$; $F_2(1, 31) = 2.88$, $p = .10$, $MSE = 728.01$. The main effect of noun position was not significant either. In the analyses of error rates, there were no significant effects.

Joint analysis of Experiments 3a and 3b. A joint analyses of the two experiments, including the additional between-subjects factor experiment (Experiment 3a vs. Experiment 3b), revealed a significant main effect of relatedness in the analysis of naming latencies, $F_1(1, 46) = 105.49$, $p < .001$, $MSE = 661.72$; $F_2(1, 31) = 26.71$, $p < .001$, $MSE = 3{,}447.71$; however, relatedness did not interact with position (Fs < 1), with experiment (Fs < 1.3), or with position and experiment (Fs < 1.2). The same pattern was observed in the analysis of error rates, although the main effect of relatedness was significant at a trend level only in the subject analysis, $F_1(1, 46) = 3.27$, $p = .08$, $MSE = 3.52$; $F_2(1, 31) = 4.95$, $p < .05$, $MSE = 1.74$ (for all interactions, Fs < 1.6). Thus, the size of the interference effects for noun positions 1 and 2 observed in Experiments 3a and 3b was highly comparable, and this was so independent of the type of materials used in the working memory task (digits vs. words). This pattern, then, suggests that—despite the additional load induced by the working memory task—both noun lemmas had been selected before speech onset.[11]

When compared with those in Experiment 1a, in which subjects had produced the same sentences without an additional task, the interference effects were much larger (38 ms vs. 18 ms, respectively), $F_1(1, 70) = 7.07$, $p < .05$, $MSE = 872.87$; $F_2(1, 31) = 15.35$, $p < .001$, $MSE = 398.80$, for the interaction of experiment (Experiments 3a and 3b vs. Experiment 1a) and relatedness. Thus, the introduction of the additional working memory task had indeed some effect in that it boosted the interference effects. But, unlike in Experiment 2, this increase in the size of the interference effect held for both noun positions, not just for the first one. This pattern might be taken as some tentative support for the notion that an utterance-related load (like the conceptual decision and format switch in Experiment 2) leads to an increase of the overall interference effects and at the same time reduces the scope of grammatical advance planning and that a load that is not directly related to utterance production, as in the present experiment, leads to an overall increase of the interference effects without affecting the scope of grammatical advance planning.

General Discussion

The present experiments addressed the question of whether grammatical advance planning in sentence production uses a planning unit of some fixed size (like the phrase or the clause) or whether speakers can flexibly adjust the scope of grammatical advance planning. In particular, we addressed the question of whether the amount of grammatical advance planning in the production of sentences of different complexity varies with cognitive load.

Using an extended picture–word interference paradigm, Experiment 1a showed similarly sized semantic interference effects for the first and the second noun in simple sentences (of the form “the [left object] is next to the [right object]”; e.g., “the frog is next to the mug”). Experiment 1b showed an increase of the interference effect for the first noun in more complex utterances (of the form “the [color] [left object] is next to the [color] [right object]”; e.g., “the blue frog is next to the blue mug”) and a much smaller though still significant interference effect for the second noun (see Figure 2 for an overall summary of the present data).

Experiment 1c demonstrated that the pattern for complex utterances in Experiment 1b is not due to the fact that the two objects always had the same color. These results thus give a first indication of variability in advance planning. The increase in interference as observed in Experiments 1b and 1c is presumably due to an

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[10] An analysis discarding trials with incorrect responses in the working memory task yielded the same pattern, a main effect of semantic relatedness and no interaction of this factor with noun position. Descriptively, the interference effects (collapsed over noun position) amounted to 36 ms in Experiment 3a and to 39 ms in Experiment 3b (as compared to 37 ms and 39 ms, when also including trials with incorrect working memory task responses).

[11] Separate analyses of fast and slow subjects yielded a pattern similar to that in the preceding experiments. For fast subjects, the interference effect was larger for the first noun than for the second noun (44 ms and 19 ms effect, respectively, averaged across Experiments 3a and 3b), while for slow subjects, the interference effect for the first noun was descriptively even smaller than the interference effect for the second noun (34 ms and 56 ms, respectively).

Table 4
Mean Naming Latencies (in Ms) and Errors Rates (in %) From Experiments 3a and 3b by Relatedness and Noun Position

	Experiment 3a: Digit memory set				Experiment 3b: Adjective memory set			
	Noun position 1		Noun position 2		Noun position 1		Noun position 2	
Relatedness	ms	%	ms	%	ms	%	ms	%
Related	830 (22)	11.8 (1.5)	844 (31)	10.8 (1.6)	865 (26)	10.2 (1.3)	853 (27)	11.2 (1.9)
Unrelated	797 (23)	8.7 (1.4)	802 (24)	10.3 (1.9)	821 (26)	9.0 (1.2)	820 (24)	9.9 (1.5)
Difference	33 (7)	3.1 (1.5)	41 (13)	0.5 (1.7)	44 (6)	1.2 (1.7)	34 (9)	1.3 (1.7)

Note. Positive difference scores reflect interference. Standard errors are given in parentheses.

increase in task demands (i.e., a more demanding utterance format; see Lavie et al., 2004). However, the fact that the increased interference effect concerned only the first noun suggests that at the same time the scope of grammatical advance planning included only the first noun phrase on a substantial proportion of trials.

More detailed analyses of these data, dividing the subjects of Experiments 1a, 1b, and 1c into groups of fast and slow responders, revealed additional evidence for flexibility in grammatical advance planning. Although the interference effects for the first noun were about equal in size for these two groups, the interference effects for the second noun turned out to be smaller for the group of fast speakers than for the group of slow speakers, and this held for the simple as well as for the complex utterances. Thus, fast speakers showed a tendency toward incremental grammatical advance planning, and slow speakers showed a tendency toward full grammatical planning of the whole utterance before utterance onset.

Why do fast speakers have a stronger tendency than slow speakers to produce sentences incrementally? One possibility is that they are able to start articulation of the first noun phrase of the utterance while planning the second noun phrase in parallel because they have more cognitive capacity available. By that argument, slow speakers would avoid parallel articulation and planning because they have less capacity. If this hypothesis were correct, the reduction of cognitive capacity by means of an additional cognitive load should lead to a smaller proportion of trials on which speakers proceed incrementally also for fast speakers and thus to an increase of the interference effect for the second noun. Experiment 2 showed, in contrast to this prediction, that an additional cognitive load effectively eliminated the interference effect for the

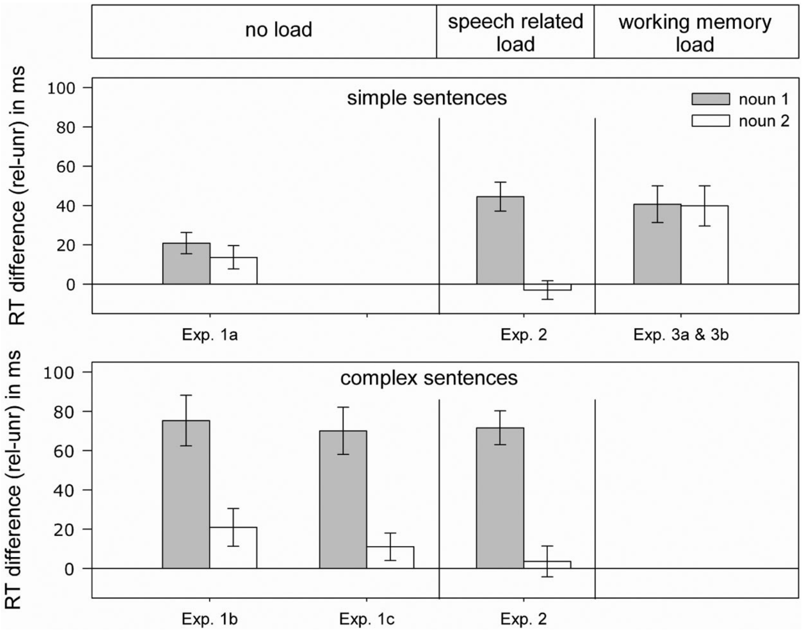

Figure 2. Mean reaction time (RT) differences (related − unrelated, in milliseconds) and corresponding standard errors for noun positions 1 and 2 in Experiments 1–3. Results for simple sentences are depicted in the top panel, and results for complex sentences are depicted in the bottom panel. The top row indicates the type of load induced in the experiments. Data are collapsed over SOAs. Positive scores reflect interference. rel = related; unr = unrelated; SOAs = stimulus onset asynchronies.

second noun, and this was the case for slow and fast speakers and for simple and complex utterances alike. Thus, incremental production seems to be cognitively less demanding than full planning; speakers cope with an increased cognitive load by reducing the span of grammatical advance planning.

In Experiments 3a and 3b, cognitive load was added by means of a working memory task. Subjects were presented with a memory set consisting of either digits or words that they had to retain in working memory while planning the production of simple sentences. This manipulation led to an increase in interference over that in Experiment 1a, in which subjects produced the same sentences without the working memory task. This increase in interference was independent of the materials used in the memory task (digits vs. adjectives), and—most important—it was obtained for both noun positions. The latter aspect suggests that despite the higher cognitive load, the scope of grammatical advance planning remained unchanged; speakers still selected both nouns before speech onset. Although it is tempting to speculate that a load manipulation that is related to the speech production process proper (Experiments 1 and 2) does affect the scope of grammatical advance planning, while a load manipulation that is not directly related to the speech production process does not (Experiment 3), possibly implying dedicated processing resources for language processing, such a conclusion would be premature. One needs to keep in mind that the load manipulations introduced in Experiments 2 versus 3 also differ in other respects (e.g., with regard to the temporal dynamics of the induced load). Whereas the additional load was imposed on the system for a restricted period of time (i.e., during initial conceptual planning) in Experiment 2, it spanned the whole speech planning process in Experiment 3, and this difference might have contributed to the differential pattern as well. However, what the results from Experiment 3 clearly show is that cognitive load per se does not selectively affect the interference patterns for initial noun phrases (as indexed by the increase in interference for both noun position 1 and noun position 2). This further validates our conclusion that the asymmetric interference pattern for noun position 1 and noun position 2 (as observed in Experiments 1b, 1c, and 2) does indeed reflect a change in the scope of grammatical advance planning.

Recently, Wheeldon and colleagues (Allum & Wheeldon, 2007, 2009; Smith & Wheeldon, 1999) proposed that advance planning with respect to lemma selection has a phrasal scope. This proposal is not necessarily in contradiction with the claim of a flexible planning scope we advance here. For Experiment 2 as well as for large proportion of the trials in Experiment 1b, our results are compatible with the phrasal scope proposal. But the present data also show that the planning scope can go beyond a phrase, in particular for slow speakers and/or under conditions of low cognitive load.

Experiment 2 showed that an additional cognitive load can reduce such a wider advance planning scope, such that the noun lemma of the second noun phrase is not accessed before speech onset. However, the cognitive load used in Experiment 2 entailed two features, namely, the conceptual decision task (decide whether the real-world size of the depicted objects is smaller or larger than a given standard) and the switch between two different sentence types (produce a simple vs. a complex sentence). Experiment 2 did not allow us to decide which of these two aspects was effective in reducing the planning scope. We therefore conducted an additional control experiment, which was identical to Experiment 2 except for the fact that subjects had to produce only one sentence format. Half of the subjects produced simple sentences for small objects and gave no response for large objects (or vice versa). The other half of the subjects produced complex sentences for small objects and gave no response for large objects (or vice versa). Thus, in this control experiment the conceptual decision task was still involved, but no switch between sentence types was required. For simple sentences, the interference effect was significant for both noun positions, though it was significantly larger for noun position 1 than for noun position 2 (41 ms vs. 17 ms, respectively). The same pattern of results was obtained for complex sentences (82 ms vs. 27 ms interference for noun positions 1 and 2, respectively). Thus, the involvement of the decision task alone is not sufficient to eliminate the interference effect for the noun in second position. Rather, the reduction of the planning scope to only the first phrase, as observed in Experiment 2, seems to be due to the additional switch between two different sentence formats (simple vs. complex sentences).

In all, then, the present data show that speakers do flexibly adjust the scope of grammatical advance planning during sentence production to task demands. In particular, our experiments demonstrated that an increase in cognitive load leads to a reduction in the scope of advance planning and a higher proportion of incrementally produced utterances.

In this article, we have been operationalizing grammatical advance planning by assessing which lemmas are retrieved prior to speech onset. This approach can be related in a straightforward way to models of grammatical encoding that assume that grammatical encoding is lexically driven (i.e., lemma access precedes the building of syntactic structures; see, e.g., Bock & Levelt, 1994; de Smedt 1990, 1996). There is an alternative account, however, according to which representations at the conceptual level can interact with syntactic processes determining word order, which in turn determine the order in which lexical elements have to be accessed (e.g., Chang, Dell, & Bock, 2006). Put differently, in these models the syntactic processes determining word order precede lexical access.

The lexically driven model by de Smedt (e.g., de Smedt 1990, 1996) allows for parallel (or partially parallel) encoding of both noun phrases in the type of sentences used in the present study as well as for just encoding the first noun phrase before articulation is initiated. Within the framework of such a model, the present data thus suggest that cognitive load reduces the scope of grammatical advance planning such that the second noun phrase is no longer included. Within the framework of models such as the one proposed by Chang et al. (2006), our data suggest that cognitive load affects the number of lexical items that are retrieved before utterance onset. It does so, however, without necessarily affecting the amount of syntactic structure that is built before speech onset. Thus, from the perspective of this type of models, the observed reduction of grammatical advance planning (primarily) concerns the "lexical filling" of a generated syntactic structure.

In conclusion, the present results provide direct experimental support for the idea that speakers flexibly adjust the scope of advance planning during grammatical encoding. Until now, this idea has been offered only informally (e.g., F. Ferreira & Swets, 2002; Levelt, 2001; Levelt & Meyer, 2000; Lindsley, 1976;

Mortensen et al., 2008) as an “escape route” to account for conflicting data in the literature.

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(*Appendices follow*)

Appendix A

Objects and Distractors Used in Experiments 1–3

Object pair		Distractor	
Object 1	Object 2	Related	Unrelated
Becher [mug][g]	*Nagel* [nail]	*Tasse* [cup]	*Socke* [sock]
Beutel [pouch][g]	*Frosch* [frog]	*Tasche* [bag]	*Nase* [nose]
Eis [ice cream][g]	*Klingel* [bell]	*Lutscher* [lollipop]	*Dolch* [dagger]
Frosch [frog][r]	*Becher* [mug]	*Kröte* [toad]	*Hupe* [horn]
Klingel [bell][r]	*Messer* [knife]	*Hupe* [horn]	*Schraube* [screw]
Korken [cork][b]	*Eis* [ice cream]	*Stöpsel* [plug]	*Wecker* [alarm clock]
Krawatte [tie][b]	*Ohr* [ear]	*Schlips* [tie]	*Wurm* [worm]
Maus [mouse][g]	*Korken* [cork]	*Ratte* [rat]	*Tasse* [cup]
Messer [knife][b]	*Raupe* [caterpillar]	*Dolch* [dagger]	*Schlips* [tie]
Mütze [cap][b]	*Uhr* [clock]	*Hut* [hat]	*Stöpsel* [plug]
Nagel [nail][b]	*Strumpf* [stocking]	*Schraube* [screw]	*Ratte* [rat]
Ohr [ear][g]	*Schlüssel* [key]	*Nase* [nose]	*Tasche* [bag]
Raupe [caterpillar][g]	*Mütze* [cap]	*Wurm* [worm]	*Dietrich* [picklock]
Schlüssel [key][r]	*Maus* [mouse]	*Dietrich* [picklock]	*Hut* [hat]
Strumpf [stocking][r]	*Beutel* [pouch]	*Socke* [sock]	*Kröte* [toad]
Uhr [clock][r]	*Krawatte* [tie]	*Wecker* [alarm clock]	*Lutscher* [lollipop]
Axt [ax][g]	*Käfig* [cage]	*Beil* [hachet]	*Piano* [piano]
Baby [baby][g]	*Mauer* [wall]	*Säugling* [baby]	*Zwinger* [kennel]
Burg [castle][r]	*Pferd* [horse]	*Festung* [fortress]	*Kiste* [box]
Cello [cello][b]	*Fass* [cask]	*Geige* [violin]	*Couch* [couch]
Fass [cask][g]	*Herd* [hearth]	*Tonne* [barrel]	*Jacke* [jacket]
Herd [hearth][r]	*Cello* [cello]	*Ofen* [stove]	*Tiger* [tiger]
Käfig [cage][r]	*Schiff* [ship]	*Zwinger* [kennel]	*Säugling* [baby]
Klavier [piano][r]	*Mantel* [coat]	*Piano* [piano]	*Boot* [boat]
Löwe [lion][g]	*Burg* [castle]	*Tiger* [tiger]	*Kuchen* [cake]
Mantel [coat][b]	*Sofa* [sofa]	*Jacke* [jacket]	*Festung* [fortress]
Mauer [wall][b]	*Klavier* [piano]	*Wand* [wall]	*Tonne* [barrel]
Pferd [horse][g]	*Torte* [torte]	*Esel* [donkey]	*Ofen* [stove]
Schiff [ship][b]	*Truhe* [chest]	*Boot* [boat]	*Beil* [hachet]
Sofa [sofa][r]	*Löwe* [lion]	*Couch* [couch]	*Geige* [violin]
Torte [torte][b]	*Axt* [ax]	*Kuchen* [cake]	*Esel* [donkey]
Truhe [chest][r]	*Baby* [baby]	*Kiste* [box]	*Wand* [wall]

Note. Approximate translations are given in brackets. Spatial position of the two objects was systematically varied. Within each object pair, distractors were only related or unrelated to object 1.
[b] Object(s) displayed in blue color. [g] Object(s) displayed in green color. [r] Object(s) displayed in red color.

Appendix B

Adjectives Used for the Working Memory Task in Experiment 3b

Approximate translations for the adjectives are given in brackets: *toll* [amazing], *echt* [authentic], *hoch* [high], *lang* [long], *frei* [free], *spät* [late], *hart* [hard], *real* [real], *rein* [pure], *lieb* [beloved].

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