

The use of lexical and syntactic information in language production: Evidence from the priming of noun-phrase structure

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Abstract

Theories of lexical representation in production provide sophisticated accounts of the way in which information is activated during lexical access (e.g., Levelt, Roelofs, & Meyer, 1999), but there has been little attempt to account for the way in which the structure of the lexical entry affects the formulation processes that underlie the production of complex expressions. This paper first outlines such an account, and then reports three experiments that investigated the priming of noun-phrase structure in dialogue. Experiment 1 showed that speakers used a complex noun phrase containing a relative clause (e.g., “the square that’s red”) more often after hearing a syntactically similar noun phrase than after hearing a simple noun phrase, and that this effect was enhanced when the head noun (“square”) was repeated. Experiment 2 showed an enhanced priming effect when prime and target contained semantically related nouns (e.g., “goat” and “sheep”). Experiment 3 showed no enhanced effect when prime and target bore a close phonological relationship (e.g., “ship” and “sheep”). These results provide support for our account, and suggest that syntactic encoding may be unaffected by phonological feedback.

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Between the generation of a preverbal message and articulation, speakers have to formulate what they want to utter in language. This process of formulation appears to proceed through a number of stages and involves different sources of information. Speakers must be able to select the appropriate words from their lexicon, place them in an appropriate order, and give them the correct phonological form. Current models of language production assume a distinction between the processes underlying the selection of lexical concepts and the generation of a syntactic plan (termed grammatical encoding), and the processes underlying the selection of word-forms and the generation of intonation (phonological encoding) (e.g., Bock & Levelt, 1994). It is

commonly assumed that these processes are lexically driven (e.g., Levelt, 1989), so that grammatical and phonological encoding rely on the retrieval of lexical information.

Most current accounts of language production assume that lexical information is not represented as an undifferentiated whole, but rather that each lexical item is separated into at least two parts, with there being a basic distinction between phonological and morphological information on the one hand, and syntactic and semantic information on the other. In support of this, there is a great deal of evidence suggesting that lexical retrieval is a two stage process, with retrieval of syntactic and semantic information preceding retrieval of word-form information. This evidence includes speech-error data (e.g., Dell, 1986; Dell & Reich, 1981; Fromkin, 1973; Garrett, 1975, 1980), tip-of-the-tongue (TOT) effects (e.g., Vigliocco, Antonini, & Garrett, 1997;

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Vigliocco, Vinson, Martin, & Garrett, 1999), neuropsychological patients (e.g., Henaff Gonon, Bruckert, & Michel, 1989; Martin, Lesch, & Bartha, 1999), electrophysiological data (e.g., Schmitt, Schiltz, Zaake, Kutas, & Münte, 2001; Van Turenhout, Hagoort, & Brown, 1998) and picture naming and lexical decision tasks (e.g., Damian & Martin, 1999; Jescheniak & Levelt, 1994; Schriefers, Meyer, & Levelt, 1990). Some of this evidence points to a further distinction between syntactic and semantic information (see Levelt et al., 1999). In keeping with this terminology, we shall refer to the level at which syntactic information is represented as the lemma stratum.

Our concern in this paper is with the representation and activation of lexical information during production. More specifically, we are concerned with the relationship between syntactic information and other aspects of lexical representation. Theories of lexical representation assume that syntactic information is stored at the lemma stratum, but have largely restricted themselves to relatively straightforward aspects of syntactic information such as grammatical category and gender (e.g., Vigliocco et al., 1997). In contrast, accounts of sentence formulation focus on the use of syntactic rules in the construction of complex expressions (e.g., Garrett, 1980). Here we are concerned with aspects of lexical representation that draw upon such combinatorial information, in a way that should help to integrate theories of lexical representation and sentence formulation. We focus on the production of complex noun phrases, in part because they provide a bridge between lexical and sentential work.

Probably the most controversial issue in lexical production is whether flow of activation between levels is purely feedforward (Levelt et al., 1999) or whether activation can feed backwards (Dell, 1986). Crucially, a feedback account predicts that activation at the phonological level can feed back to the lemma level. In the following two sections, we consider the predictions of an extension of Levelt et al.'s model for activation of syntactic analyses (Branigan & Pickering, in press; Pickering & Branigan, 1998). We then propose how to investigate these accounts, and describe three syntactic priming experiments (Bock, 1986a, 1986b) in dialogue that help determine how syntactic information is accessed and used within the production lexicon.

Activation of lexico-syntactic information in a feedforward account

Fig. 1 shows a model of lexical access based on Levelt et al. (1999), where conceptual, lemma and word-form levels (or strata) of representation correspond to conceptual, lexico-syntactic, and phonological information, respectively. (It ignores details of semantic representa-

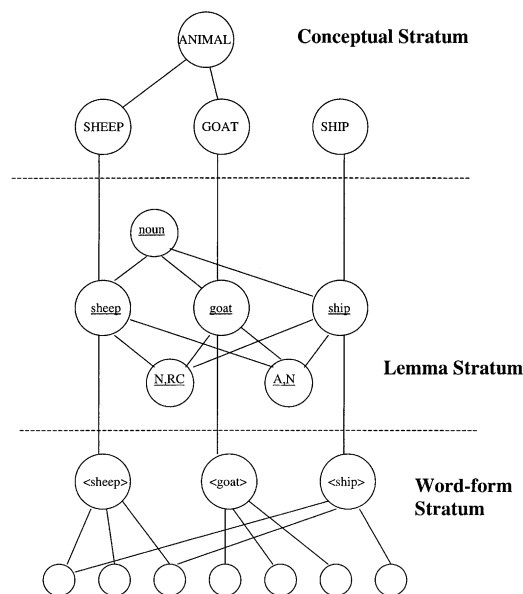


Fig. 1. Model of lexical access based on Levelt et al. (1999). Lines represent structure of representations, not direction of activation flow.

tion, and represents structure rather than direction of activation flow.) In Levelt et al., the lemma level purely contains syntactic information. This contrasts with accounts that assume that lemmas are specified for semantic information (Kempen & Huijbers, 1983; Levelt, 1989), and accounts in which the lemma level is organized according to semantic fields (e.g., Butterworth, 1989; Zorzi & Vigliocco, 1999). We assume Levelt et al.'s account for the purposes of this introduction.

The conceptual level represents semantic information. Within Levelt et al.'s (1999) model, this is done by links between nodes rather than by decomposition. The conceptual node SHEEP is linked to the lemma node *sheep*. The lemma level incorporates syntactic information (Pickering & Branigan, 1998; Roelofs, 1992, 1993). In Fig. 1, the lemma node *sheep* is linked to a node specifying that it is a noun. The lemma level also contains other syntactic information, such as the count/mass status of nouns (e.g., *sheep* is linked to a count-noun node), number and gender (if any), as well as combinatorial information (see below). We have ignored featural nodes in Fig. 1 for the sake of simplicity. Note also that the *noun* node is "shared" between *sheep* and *goat*, thereby reducing redundancy. The lemma node *sheep* is then linked to the word-form node <sheep>, which is in turn linked to phonological information (in effect, the phonemes that make up the spoken word "sheep").

Activation feeds from the conceptual to the lemma to the word-form level. When the speaker decides to utter "sheep," the conceptual node SHEEP gets activated.

It spreads activation to ANIMAL and therefore to the conceptual node GOAT (alternatively, SHEEP might spread activation directly to related concepts such as GOAT, but such differences at the conceptual stratum are irrelevant for our purposes). Conceptual nodes spread activation to their associated lemma nodes in proportion to their activation. Activation then spreads from the conceptual to the lemma level. This means that the lemma node *sheep* receives most activation, but the activation of the conceptual node GOAT means that the lemma *goat* also receives some activation from its conceptual node. As the lemmas become activated, syntactic information associated with them will become available, so that (for example) the noun node also becomes activated.

At this point, lexical access occurs. A single lemma is chosen, with probabilities depending on levels of activation. Normally the chosen lemma will correspond to the conceptual node activated by the pre-verbal message, in this case SHEEP. (However, if *goat* had also received activation from another source, such as from the word “goat” in a picture-word interference task, then *goat* would have much more similar activation to *sheep*.) Activation then spreads from the lemma *sheep* to the word-form <sheep>, thereby activating the morphological and phonological properties of “sheep.” The model rules out two forms of activation. Because a single lemma is selected before phonological encoding, there is no phonological activation of semantic competitors like “goat.” Additionally, there is no feedback from the word-form to the lemma level, so that the lemma *sheep* receives no activation from the word-form <sheep>. This lack of feedback effectively separates the lemma and word-form levels into two discrete stages in production, and is of most relevance to this paper.

Another form of feedforward account allows cascaded activation between the lemma and word-form levels, so that more than one lemma can activate its associated phonological form. For example, Peterson and Savoy (1998) provided evidence for activation of phonological forms associated with near synonyms. Caramazza and Miozzo (1997) proposed a cascaded feedforward account, but in the context of a model that did not include a lemma stratum separate from the word-form stratum.

Activation in interactive accounts

Interactive accounts assume overlapping activation of semantic and phonological information (e.g., Dell, 1986, 1988; Dell & O’Seaghdha, 1992; Harley, 1984; Mackay, 1987; Martin, Weisberg, & Saffran, 1989; Stemberger, 1985). They generally allow cascaded activation of word forms, but in addition allow feedback from the phonological to the semantic and syntactic

levels (though cf. Humphreys, Riddoch, & Quinlan, 1988).

In Dell’s (1986) account, activation cascades from a lexical level to the phonological level, so that activation of multiple lexical nodes (e.g. *sheep* and *goat*) can lead to the activation of both sets of phoneme nodes (/ʃ/ /i/ /p/ and /g/ /əʊ/ /t/) at the same time. (We assume that lexical nodes are broadly analogous to lemma nodes in Levelt et al.’s model). Importantly, activation also feeds back from phoneme nodes to lexical nodes, so that activation of /ʃ/ and /p/ leads to the activation of *ship*, as a result of the shared phonemes between *ship* and *sheep*. Whereas in feedforward accounts, production of *sheep* leads to the activation of *goat*, in interactive accounts, production of *sheep* leads to the activation of both *goat* and *ship*.

The representation of syntactic information and its use in production

As noted above, we need to expand any account of word production in order to show how they can be applied to the construction of syntactically complex expressions. To do this, we relate the account of the lemma level proposed by Pickering and Branigan (1998) with the conceptual and word-form levels proposed in Levelt et al. (1999). Pickering and Branigan assumed that a lemma node (e.g., *give*) was linked to nodes specifying category information (e.g., *Verb*), featural information (e.g., singular, present tense), and combinatorial information (specifying the ways in which it can combine with other elements to form possible expressions). Pickering and Branigan assumed that an *NP,NP* combinatorial node is activated when “give” is used in the *double object* construction with two post-verbal noun phrases (e.g., “give the boy a book”) and that an *NP,PP* combinatorial node is activated when it is used in the *prepositional object* construction with a noun phrase and a prepositional phrase (e.g., “give a book to the boy”) (see also Pickering, Branigan, & McLean, 2002). More generally, the activation of combinatorial nodes is related to the construction of constituent-structure representations. They did not commit to a precise specification of the circumstances under which particular nodes are activated. However, Bock and Loebell (1990) found that sentences containing a locative *by*-phrase adjunct strongly prime the production of passives containing an agentive *by*-phrase argument. On this basis, Pickering and Branigan suggested that the same node is activated whether the phrases serve as arguments or adjuncts of the head, and hence that the nodes are unlikely to correspond to traditional subcategorization frames. The second important aspect of Pickering and Branigan’s (1998) model is that category, featural, and combinatorial nodes are shared, in a way that reduces

redundancy. This is represented in Fig. 1, where the lemma nodes *sheep* and *goat* are both linked to the same *Noun* node.

The main evidence for this account of the lemma level comes from syntactic priming. In a classic study, Bock (1986b) found that speakers tended to repeat syntactic structure during language production, so that they perseverated in the production of passives, prepositional object constructions, and so on. It appears that the syntactic structure of participants' previous utterances affected their subsequent utterances, and that alternative explanations in terms of lexical, semantic, or prosodic repetition cannot explain the data (Bock, 1989; Bock & Loebell, 1990). The effects appear to be quite general, in that they occur in different languages, constructions, and paradigms (Bock, Loebell, & Morey, 1992; Branigan, Pickering, & Cleland, 2000; Hartsuiker & Kolk, 1998; Hartsuiker, Kolk, & Huiskamp, 1999; Hartsuiker & Westenberg, 2000; Pickering & Branigan, 1998; Potter & Lombardi, 1998; see Pickering & Branigan, 1999), and response time is affected as well as form (Corley & Scheepers, 2002; Smith & Wheeldon, 2001). In a written completion task, Pickering and Branigan (1998) found priming whether or not a dative verb like *give* was repeated between prime and target sentences, but enhanced priming when it was repeated (see also Branigan et al., 2000).

Producing "gives" in "gives a book to the boy" (for instance) causes the activation of the *give* node and the *NP,PP* node (as well as category and feature nodes). The *NP,PP* node retains activation at least temporarily (cf. Bock & Griffin, 2000; Branigan, Pickering, & Cleland, 1999 on the time-course of priming), and the speaker is therefore more likely to use the node again if possible (and use it more quickly; Corley & Scheepers, 2002). But in addition, the concurrent activation of the lemma node *give* and the combinatorial node *NP,PP* leads to a strengthening of the link between them and hence enhanced priming when "give" is repeated. Pickering and Branigan (1998) also found no enhanced priming when the form of the verb was repeated compared with a verb differing in tense, aspect, or number; this is predicted because the activated link is between combinatorial node and lemma node, which is featurally unspecified. Using the same constructions, Branigan et al. (2000) found syntactic priming and enhanced priming with verb repetition when people heard rather than produced the target utterance (see below for details), indicating that merely comprehending an utterance is enough to produce priming (see also Potter & Lombardi, 1998).

Pickering and Branigan's (1998) account deals only with the lemma level, not with its interactions with the other levels, and is specifically concerned with verbs. Fig. 1 in contrast is concerned with all three relevant levels and is framed in terms of nouns rather than verbs.

If the account is general, then it should of course hold for nouns as well as verbs. Noun lemma nodes obviously link to category and featural nodes (e.g., number, gender, count/mass status). The location of featural nodes at this level accords with findings of studies of TOT and anomia, in which information associated with grammatical features can be accessed without phonological information (Badecker, Miozzo, & Zanuttini, 1995; Caramazza & Miozzo, 1997; Vigliocco et al., 1997, 1999). Nouns also have combinatorial properties, with some nouns taking arguments (e.g., "brother" can take an argument like "of Mary"), and probably all nouns can combine with adjunct phrases (e.g., "sheep" with the relative clause "that is red"). Hence, we assume that noun lemmas also link to combinatorial nodes, just as verb lemmas do (Pickering & Branigan, 1998).

Let us now focus specifically on the adjectival modification of nouns. A picture of a red sheep can be described as "the red sheep" or "the sheep that is red" (among other ways). "The red sheep" involves pre-nominal adjectival modification, whereas "the sheep that is red" involves a (post-nominal) relative clause. The former involves a construction that would traditionally be generated using a phrase-structure rule in which an intermediate projection of noun (N') rewrites as an adjective followed by a noun; the latter would involve rewriting N' as a noun followed by a relative clause. In both cases, the determiner is combined with N' to produce a complete noun phrase (e.g., Jackendoff, 1977). We assume that each construction is associated with a combinatorial node, which we call the *A,N* and *N,RC* nodes, respectively. So uttering "sheep" in the phrase "the red sheep" leads to the activation of the lemma node *sheep*, the combinatorial node *A,N*, and the link between them; and uttering "sheep" in the phrase "the sheep that is red" leads to the activation of the lemma node *sheep*, the combinatorial node *N,RC*, and the link between them. Category and featural nodes are also activated (e.g., the noun node and the singular node), but we shall not discuss these further.

This account of nominal representation at the lemma stratum makes two predictions (even before we consider the relationship with the conceptual and word-form strata). First, it should be possible to prime the production of complex noun phrases. If people process (i.e., produce or comprehend) a noun phrase employing the pre-nominal construction, they should be more likely to produce another noun phrase employing the pre-nominal construction; whereas if they process a noun phrase employing the relative-clause construction, they should be more likely to produce another noun phrase employing the relative-clause construction. This prediction follows from the assumption that combinatorial nodes retain activation after use. Second, this tendency should be increased if the same head noun is used in both constructions, on the assumption that the link between

the lemma node and the combinatorial node retains activation as well as the combinatorial node itself. Note that an explanation of such priming in terms of lexical repetition (“that” and “is” in the relative-clause construction) could not account for increased priming following repetition of the head noun. Additionally, there is good evidence against explanations of syntactic priming in terms of repetition of closed-class words (Bock, 1989; Bock & Loebell, 1990; Pickering et al., 2002) and “that” in particular (Ferreira, 2003).

Now consider the effects of interactions between strata. According to both feedforward and interactive accounts, the preparation of “the sheep that is red” leads to the activation of the concept SHEEP. This causes the semantically related concept GOAT to be activated as well, though to a lesser extent than SHEEP. This in turn leads to the strong activation of the lemma *sheep* and the weaker activation of *goat*. In addition, the combinatorial node *N,RC* gets activated. Hence, the link between *sheep* and *N,RC* gets strongly activated, and the link between *goat* and *N,RC* gets activated more weakly, but more strongly than the link between *N,RC* and a lemma associated with a semantically unrelated word such as *door*. According to the above account, production of “the sheep that is red” will increase the likelihood of producing “the sheep that is red” again (rather than “the red sheep”) to the greatest extent, but, most critically, it will also increase the likelihood of producing “the goat that is red” to a greater extent than it will increase the likelihood of producing “the door that is red.” In other words, syntactic priming should be enhanced when the head noun of the target is semantically related to the head noun of the prime versus when the nouns are semantically unrelated.

The feedforward and interactive accounts diverge, however, when considering the effects of phonological relatedness. We will return to this issue before Experiment 3.

Syntactic repetition in dialogue

Natural dialogue is extremely repetitive (e.g., Schenkein, 1980; Tannen, 1989). Hence it is not surprising that experimental research into dialogue also demonstrates strong tendencies for people to employ referring expressions that have recently been used by their interlocutors (Brennan & Clark, 1996; Garrod & Anderson, 1987) and to repeat description schemes (e.g., referring to position in a maze using coordinates; Garrod & Anderson, 1987). Garrod and Anderson argued that interlocutors use a principle of *input-output coordination*, in which they tend to use the rules and representations that they had just used in comprehension when they produce their next utterance. Such tendencies towards repetition may help the construction of aligned

situation models (Zwaan & Radvansky, 1998), which are presumably necessary for successful communication (see Pickering & Garrod, in press).

Hence, we might predict syntactic repetition to occur in dialogue. Levelt and Kelter (1982) found that speakers tended to reply to “What time do you close?” or “At what time do you close?” (in Dutch) with a congruent answer (e.g., “Five o’clock.” or “At five o’clock.”), and Schenkein (1980) and Weiner and Labov (1983) also found tendencies toward syntactic repetition in dialogue transcripts. However, it is very difficult to determine whether these effects were due to syntactic priming or to priming at another level (e.g., repetition of “At”).

Branigan et al. (2000) looked at syntactic repetition in dialogue using a confederate priming technique. Pairs of speakers took it in turns to describe pictures to one another, and to match pictures to their partner’s description. One speaker was in fact a confederate of the experimenter and was scripted to produce either a prepositional-object or a double-object description of a card on experimental trials. Branigan et al. (2000) found that naïve participants showed a strong tendency to use the same structure as the utterance they had just heard. As the prime and target pictures did not contain the same entities and the message produced in both the prepositional-object and double-object forms were essentially the same, they argued that the effect was caused by a tendency to mirror the syntactic structure of interlocutors. They argued that their results were inconsistent with an account of priming which was based on the activation of procedures associated with producing syntactic form (e.g., Bock & Loebell, 1990), on the assumption that the procedures involved in comprehension and production are not the same (see also Potter & Lombardi, 1998). Instead, the results supported the model proposed by Pickering and Branigan (1998) where priming is a result of residual activation at the lemma stratum (and hence that the lemma stratum is accessed during comprehension as well as production, in accord with Levelt et al., 1999). Importantly, priming was enhanced when the verb was repeated between prime and target, just as in production-to-production priming (Pickering & Branigan, 1998). Moreover, effects were numerically larger than in published experiments using sentence production in isolation (e.g., Bock, 1986a, 1986b; Pickering & Branigan, 1998; Potter & Lombardi, 1998), presumably as a result of the particular importance of aligning representations in dialogue. Hence, the confederate-scripting technique should be especially appropriate for addressing the questions discussed above.

Below we report three experiments in which a naïve participant and a confederate described cards that depicted objects like a red sheep or a pink door and then found the card that corresponded to their interlocutor’s description. On critical trials, the confederate produced

either a description involving a pre-nominal adjective (e.g., “the red sheep”) or a relative clause (e.g., “the sheep that is red”), and the naïve participant then produced a description of another card. Experiment 1 used shapes and manipulated whether the shape was repeated and whether the color was repeated between prime and target. Experiment 2 used pictures of everyday objects (e.g., a sheep, a door) and manipulated whether prime and target nouns were the same, semantically related, or unrelated. Experiment 3 replaced the semantically related conditions with phonologically related ones.

Experiment 1

Method

Participants

Sixteen students from the University of Edinburgh community were paid to participate. We term these *naïve participants* (to distinguish them from the confederate, who is also a participant in the dialogue).

Items

We prepared four equivalent sets of 150 cards, consisting of 15 shapes (arrow, bar, circle, club, cross, diamond, heart, moon, oval, ring, spade, square, star, sun, and triangle) in 10 colors (black, blue, brown, green, gray, orange, pink, purple, red, and yellow). All shapes and colors were simple and easy to recognize. The confederate and the naïve participant each had two sets of cards; one was the *description* set of cards which they described to their partner, and the other was the *matching* set of cards from which they selected cards to match their partner's descriptions.

From these cards, we constructed 48 items (see Appendix), defined as a pairing of a (scripted) description of a prime card in the confederate's description set with a target card in the naïve participant's description set. Each shape appeared as a target 3 or 4 times, and each color appeared 4 or 5 times, but no pairing of color and shape was repeated. There were eight conditions, which differed with respect to whether the noun was repeated between prime and target, whether the adjective was repeated between prime and target, and whether the pre-nominal or the relative-clause construction was used in the prime. For example, one item consisted of the pairing of (1a–h) with a picture of a red square.

- 1a. The red square (same adjective, same noun, pre-nominal)
- 1b. The square that's red (same adjective, same noun, relative clause)
- 1c. The red diamond (same adjective, different noun, pre-nominal)
- 1d. The diamond that's red (same adjective, different noun, relative clause)

- 1e. The green square (different adjective, same noun, pre-nominal)
- 1f. The square that's green (different adjective, same noun, relative clause)
- 1g. The green diamond (different adjective, different noun, pre-nominal)
- 1h. The diamond that's green (different adjective, different noun, relative clause)

Hence, the eight conditions were defined by the combination of three factors: Adjective (same vs. different adjective) \times Noun (same vs. different noun) \times Prime Construction (pre-nominal vs. relative-clause prime).

We constructed eight item lists, such that each list contained six items in each condition, and one version of each item. Each list also contained 48 fillers, again consisting of a scripted description of a card from the confederate's description set plus a target card from the naïve participant's description set. Fillers always involved different nouns and adjectives for prime and target. The confederate produced the pre-nominal construction for half the fillers and the relative-clause construction for the other half. The lists were individually randomized with the constraint that exactly one filler pair intervened between each item. The first pair of cards to be described in each experimental session was always a filler pair. Filler pairs were included so that the relationship between prime and target on some experimental items would be less obvious.

Procedure

Fig. 2 shows a diagram of the experimental set up for all three experiments. The participants were seated on either side of a table, with a wooden screen between them so that they could not see the other person's cards. Each participant had a card-file box which contained 96 cards from their description set (48 experimental cards and 48 filler cards, placed in the appropriate order), and the complete matching set of 150 cards, laid out on the

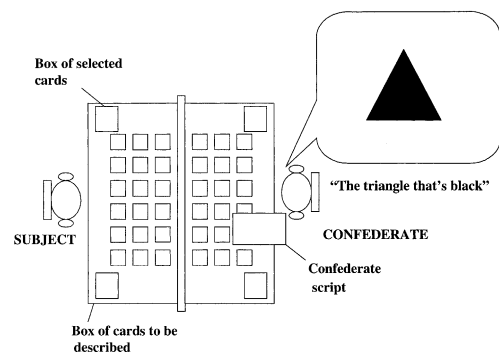


Fig. 2. Experimental set-up of confederate priming technique.

table in a grid (15 cards wide and 10 cards deep, with each shape arranged in a group 5 wide by 2 deep). Each participant also had an empty card-file box into which they placed the cards that they selected. In addition, the confederate was provided with a script.

In a set of written instructions, both participants were told that the experiment was concerned with how well people communicate when they cannot see each other, and that the goal was to end up with a set of cards in the same order as their partner's. The participants therefore had two tasks: the first was to describe the cards in the box in front of them to their partner; the second was to listen to their partner's description, pick out the card from the table which matched the description, and place it in the empty box. The participants alternated throughout the experiment, so that the confederate described a card from her description set, the naïve participant found the card in his matching set, the naïve participant described a card from his description set, and the confederate found the card in her matching set. After describing a card from the description set, participants placed the card in the lid of the box. They were instructed that they could say "Please repeat" if they wished to hear a description again, but nothing else. Participants were told to ask about anything they did not understand before the experimental session began. The experimenter and the confederate behaved as if the confederate were a naïve participant throughout the experimental session. The session lasted about 30 min.

The experimental session was recorded onto audiotape and subsequently transcribed. Participants' descriptions were scored as Pre-Nominal, Relative Clause, or Other. A *Pre-Nominal* utterance was defined as an utterance where the adjective preceded the noun (e.g., "red square," "the red square," "a red square"). A *Relative Clause* utterance was defined as an utterance where the noun was followed by a post-nominal phrase containing the adjective (e.g., "square that's red," "the square that's red," "square that is red," "the square that is red," "square which is red," "the square which is red"). Hence, utterances scored as either *Pre-Nominal* or *Relative-Clause* had to consist of a grammatical noun phrase, except that a determiner could be omitted. All other utterances were scored as *Other* (e.g., "square red").

Every participant produced 48 target utterances, six in each of the eight priming conditions defined by the combination of the Adjective (same vs. different adjective) \times Noun (same vs. different noun) \times Prime Construction (pre-nominal vs. relative clause prime) factors. All factors were within-subjects and -items.

Results and discussion

Other responses accounted for 0.5% of target responses (four responses). The vast majority of Relative Clause descriptions included the word "that" (less than

1% contained "which"). We computed a measure which was designed to determine the relative proportions of pre-nominal and relative-clause target responses in each of the priming conditions. This measure (*Pre-Nominal Target Ratio*) was the number of pre-nominal target responses divided by the sum of pre-nominal target responses and relative-clause target responses (the use of pre-nominal rather than relative-clause responses is arbitrary). Obviously, the low proportion of Other responses meant that this measure was very similar to a measure based simply on the proportion of pre-nominal or relative-clause responses, but it was used for comparison with other research in which higher proportions of other responses occurred (e.g., Pickering et al., 2002). We performed analyses of variance treating participants ($F1$) and items ($F2$) as random effects.

Proportions of target responses in the different conditions are reported in Fig. 3. Three-way ANOVAs revealed a main effect of Prime Construction ($F1(1, 15) = 18.15$, $MSE = .066$, $p < .005$; $F2(1, 47) = 41.95$, $MSE = .11$, $p < .001$), with naïve participants being 19% more likely to produce a target utterance with the same construction as the confederate's prime utterance than with the alternative construction. There was also an interaction between Noun and Prime Construction ($F1(1, 15) = 5.32$, $MSE = .031$, $p < .05$; $F2(1, 47) = 9.99$, $MSE = .052$, $p < .005$), with a 27% priming effect when prime and target used the same noun, and a 12% priming effect when prime and target used different nouns. There was a marginal interaction of Adjective and Prime Construction, significant across items only ($F1(1, 15) = 2.08$, $MSE = .055$, $p = .17$; $F2(1, 47) = 4.66$, $MSE = .028$, $p < .05$), with a 24% priming effect when prime and target used the same adjective, and a 13% priming effect when they used different adjectives. Planned comparisons indicated that

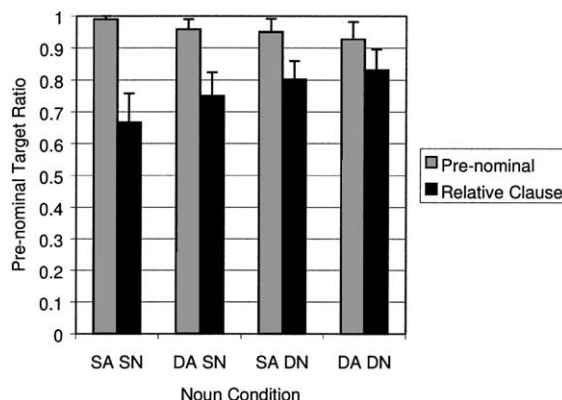


Fig. 3. Pre-nominal target ratios for Experiment 1 across all conditions. SA SN: same adjective, same noun (between prime and target); DA SN: different adjective, same noun; SA DN: same adjective, different noun; DA DN: different adjective, different noun. Bars represent standard error values.

there was a priming effect (marginal by subjects) even when there was no lexical overlap between the adjective and noun in prime and target sentences ($F(1, 15) = 3.58$, $MSE = .021$, $p = .078$; $F(2, 47) = 7.42$, $MSE = .051$, $p < .01$). No other effects approached significance.

The overall 19% priming effect is consistent with the finding of Branigan et al. (2000) that speakers tend to repeat the construction used by their interlocutors in dialogue. Moreover, it demonstrates that the tendency to repeat syntactic structure occurs at the level of the noun phrase. The fact that priming is greater when the noun was repeated than when it was not is also consistent with Branigan et al., and indicates that the additional effect due to repeating a head occurs for nouns as well as verbs. These results therefore provide support for the extension of Pickering and Branigan's (1998) model to noun phrases. As the effect of repeating adjectives was not fully significant we shall not discuss it further.

Experiment 2

Experiment 2 was concerned with the relationship between activation at the conceptual stratum and at the lemma stratum. To investigate this, it compared priming when the prime and target shared the head noun, when the head nouns were different but semantically related, and when they were unrelated. This experiment employed pictures of everyday objects so that we could manipulate their semantic relationship. It also allowed us to investigate whether the most important results from Experiment 1 generalize to a new set of nouns.

Method

Participants

Eighteen students from the University of Edinburgh community were paid to participate as naïve participants. We excluded one further student who had realized that the experiment involved a confederate.

Items

We prepared four equivalent sets of 150 cards, consisting of 50 different objects, in three different colors (red, green, and pink). The objects were easily recognizable, and consisted of pairs of semantically related objects that were members of the same category. We used category co-membership as the criterion of semantic relatedness (rather than, for example, association) because of its clear effects in studies of language production (e.g., in picture-word interference studies; Lupker, 1979). The colors have common one-syllable names that do not begin with the phoneme /b/, because Experiment 3 employed many nouns beginning with /b/ (see below). Sets of cards were distributed as in Experiment 1.

We constructed 36 experimental items consisting of a (scripted) description of a prime card from the confederate's description set and a target card from the naïve participant's description set (see Appendix). The six conditions differed with respect to whether prime and target contained the same noun, semantically related nouns, or unrelated nouns, and with respect to whether the pre-nominal or the relative-clause construction was used in the prime. For example, one item consisted of the pairing of (2a–f) with a picture of a red sheep:

- 2a. The red sheep (same noun, pre-nominal)
- 2b. The sheep that's red (same noun, relative clause)
- 2c. The red goat (semantically related noun, pre-nominal)
- 2d. The goat that's red (semantically related noun, relative clause)
- 2e. The red knife (unrelated noun, pre-nominal)
- 2f. The knife that's red (unrelated noun, relative clause)

Hence, the six conditions were defined by the combination of two factors: Semantic Relatedness (same vs. semantically related vs. unrelated noun) \times Prime Construction (pre-nominal vs. relative-clause prime).

We constructed six lists of items, each containing six items in each condition, and one version of each item. Each list also contained 36 filler pairs (with the confederate using each construction half of the time), with the cards in a pair using semantically unrelated nouns and different colors. In all other respects, the lists were constructed in the same way as Experiment 1.

Procedure

The cards were arranged by object in sets of three (e.g., red arm, green arm, and pink arm), in a grid 15 cards wide by 10 cards deep. Objects were laid out in alphabetical order (partly to facilitate the search for a card, and partly to avoid clustering of semantically related items). To reduce the likelihood of errors, both participants were asked to make sure they knew what each object was before the experiment; the instructions included a list of the object's names. Then both participants read out the names of the objects to their partner, and the experimenter corrected any mistake. In all other aspects, the experimental session was the same as Experiment 1.

Results and discussion

There was only 1 Other response (0.2% of target responses). Proportions of target responses in the different conditions are reported in Fig. 4. Two-way ANOVAs on the Pre-Nominal Target Ratios for each condition revealed a main effect of Prime Construction ($F(1, 17) = 26.62$, $MSE = .085$, $p < .001$; $F(2, 35) = 106.78$, $MSE = .041$, $p < .001$), with naïve participants being 29% more

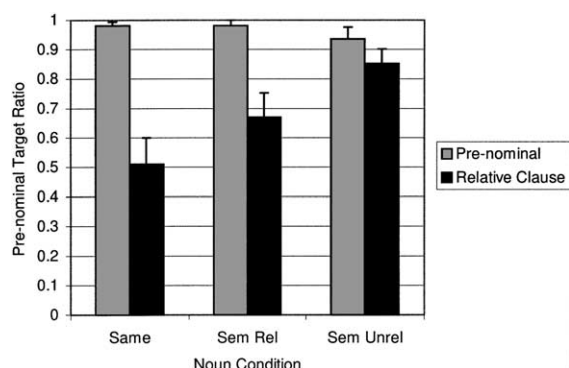


Fig. 4. Pre-nominal target ratios for Experiment 2 across all conditions. Same: Same noun (between prime and target); Sem Rel: semantically related prime noun; Sem Unrel: semantically unrelated prime noun. Bars represent standard error values.

likely to produce a target utterance with the same construction as the confederate's prime utterance than with the alternative construction. There was also an interaction between Prime Construction and Semantic Relatedness ($F(2, 16) = 11.60$, $MSE = .031$, $p < .005$; $F(2, 34) = 19.37$, $MSE = .042$, $p < .001$), with 47% priming when prime and target used the same noun, 31% priming when prime and target used semantically related nouns, and 8% priming when prime and target used unrelated nouns. Planned comparisons revealed stronger priming when prime and target nouns were semantically related versus when they were unrelated ($F(1, 17) = 7.05$, $MSE = .033$, $p < .05$; $F(1, 35) = 9.50$, $MSE = .049$, $p < .01$), and stronger priming (marginal by subjects) when prime and target nouns were the same versus when they were semantically related ($F(1, 17) = 3.62$, $MSE = .032$, $p = .074$; $F(1, 35) = 5.55$, $MSE = .042$, $p < .05$). When prime and target were unrelated, the 8% priming was non-significant ($F(1, 17) = 2.68$, $MSE = .024$, $p = .12$; $F(1, 35) = 3.48$, $MSE = .038$, $p = .07$).

The overall priming effect replicated the results from Experiment 1. More interestingly, the magnitude of this effect was affected by the relationship between prime and target nouns. In particular, naïve participants tended to repeat the construction just used by the confederate to a greater extent if prime and target nouns were semantically related than if they were unrelated. Hence, these results provides strong support for the account represented in Fig. 1. The preparation of an utterance such as a noun phrase leads to the activation of the concept associated with the head noun and lesser activation of semantically related concepts. Their lemmas are activated in proportion to their conceptual activation. Additionally, the combinatorial node associated with the syntactic structure of the utterance is activated, and the links between the combinatorial node and all activated lemma nodes are enhanced. The results do not dis-

criminate between feedforward (including cascading) and interactive versions of the account.

Experiment 3

Experiment 2 provides evidence that syntactic priming can be enhanced by semantic relatedness between prime and target. This is explicable in terms of a feedforward or an interactive account. In Experiment 3, we ask whether syntactic priming can be enhanced by phonological relatedness between prime and target. Such a result would provide strong evidence for an interactive account and against a feedforward account. On the other hand, the lack of an effect of phonological relatedness would provide some evidence against particular interactive accounts, specifically interactive accounts in which phonological feedback can influence choice of syntactic structure.

In terms of Fig. 1, a feedforward account only allows information to flow downwards between the strata, whereas an interactive account allows information to flow from the phonological stratum to the lemma stratum. In the process of producing "the sheep that is red," for instance, both feedforward and interactive accounts propose that activation of the lemma SHEEP should lead to the activation of the word-form <sheep>, and the phonemes /ʃ/, /i/, and /p/. According to the interactive account, this should lead to the activation of the word-form <ship>, and hence the lemma *ship*. As the combinatorial node *N,RC* is also activated, the link between *ship* and *N,RC* should be strengthened.

In our explanation of Experiment 2, the production of "the sheep that is red" led to the activation of *sheep* and *N,RC*, but also to the activation of *goat* and the strengthening of the link between *goat* and *N,RC*. This resulted in the enhanced priming of "the goat that is red" relative to a baseline containing an unrelated noun. Hence, if the interactive account is correct, the production of "the sheep that is red" should lead to the strengthening of the link between *ship* and *N,RC* and hence enhanced priming of "the ship that is red" relative to a baseline such as "the door that is red." In contrast, the feedforward account predicts no feedback from <sheep> to *ship*. This account therefore predicts no enhancement of "the ship that is red" relative to "the door that is red."

Hence, the interactive account derived from Fig. 1 predicts enhanced syntactic priming as a result of a strong phonological relationship between prime and target nouns. However, it is important to stress that interactive accounts in general need not predict such an effect. Most interactive accounts propose that processes concerned with the construction of phonological form influence the processes involved in word selection, but are silent about whether they affect syntactic encoding

(e.g., Dell, 1986). Some of the evidence for such accounts comes from speech errors (in particular, the apparent over-occurrence of “mixed” errors that are both phonologically and semantically related to the correct form; Dell & Reich, 1981; Stemmer, 1985) and some from experiments (Cutting & Ferreira, 1999; Damian & Martin, 1999; Ferreira & Griffin, 2003). An interactive account that explains such data may also predict that phonological factors will affect syntactic choice, but it need not do so.

Currently there is very little evidence about whether phonological relations have an effect on syntactic choice. First, Bock (1986a) investigated whether the choice of whether to describe a picture using an active (e.g., lightning is striking the church) versus passive (the church is being struck by lightning) was affected by the prior presentation of a prime word that was either semantically related to one of the nouns (worship, thunder) or phonologically related (search, frightening). In two experiments, semantic primes had a small but significant priming effect (4.6% and 3.3%), with a tendency to begin the utterance with the word related to the prime. In contrast, phonological primes had non-significant tendency in the opposite direction (2.4% and 1.7%). The first experiment largely employed vowel similarity, whereas the second experiment largely employed consonant similarity. Bock (1987) explored the same question using phonological primes only, but increased the phonological similarity between the prime and one of the nouns in the picture, so that they always shared syllable onsets, and, for one syllable primes, only differed with respect to the consonantal endings. Pictures described transitive events (as in Bock, 1986a) or two items that had to be described using a conjoined noun phrase. Priming effects were small but significant, and were numerically larger for the transitive events. Similar effects occurred when participants simply had to list the two nouns.

These results provide some reason to expect phonological effects on syntactic encoding. However, there are considerable differences between Bock’s (1987) approach and our own, essentially because Bock used a word as a prime whereas we use a syntactic structure. One possibility, raised by Bock (1987), is that a prime made it more difficult to retrieve a phonologically related form, thereby leading participants to produce a sentence structure in which that form was used later. Although this is compatible with feedback, it is also compatible with an account in which the processor abandons a syntactic structure if it cannot straightforwardly find the words that are compatible with that structure (cf. Levelt & Maassen, 1981; see Levelt, 1989, pp. 279–281 for discussion). Bock’s results do not provide a clear indication of whether phonological relationships between head nouns will affect priming within our paradigm. Additionally, the results of Experiment 2 and our model

suggest that if phonological relationship affects syntactic priming, then its effects should be facilitatory rather than inhibitory.

Other investigations into phonological impacts on selection of lemmas or concepts have generally been concerned with lexical access, and so do not necessarily make predictions about selection of construction type (e.g., Damian & Martin, 1999), though there has been some discussion of phonological effects on the specific issue of subject-verb agreement (see Vigliocco & Hartsuiker, 2002, for a review). Hence, there is very little evidence either for or against the interactive account discussed above.

In order to investigate the effects of phonological relatedness on syntactic priming, we had to make a decision about the way in which prime and target nouns should be phonologically related. Previous experiments investigating the effects of phonological relations in production have varied considerably in this respect. As stated above, Bock (1986a) used consonant and vowel similarity, whereas Bock (1987) used primes and targets that shared onsets and often only differed in their final consonant cluster. In lexical-access studies a range of different relations have been used. Significant effects generally occur when the relationship is considerably more distant than Bock (1987). In a picture-word interference task, Damian and Martin (1999) found phonological effects using items which overlapped in initial phoneme but not necessarily vowel sound (e.g., “apple-apricot”; “spoon-spatula”). In such tasks, priming effects occur for words whose phonemes overlap either at the beginning or the end (e.g., Jescheniak & Schriefers, 1998; Meyer & Schriefers, 1991; Schriefers et al., 1990; cf. Peterson & Savoy, 1998). These studies demonstrate that phonological effects in lexical access are quite robust, in two respects. First, such priming occurs as a result of overlap of different parts of a word (e.g., beginning vs. end). Second, it does not depend on exceptionally close relationships between the phonological form of prime and target.

In order to give us the most chance of detecting a phonological effect on syntactic priming, we endeavored to make prime and target nouns as closely related as possible. Because the overlap of both initial phonemes and final phonemes can cause priming, we employed primes which had the same initial and final phonemes (e.g., “sheep-ship,” “bell-ball”). Most of our items involved different word-medial vowels, though some used the same vowel (e.g., “bed-bread”). Over half of the items only differed in one phoneme. Overall, our items were more closely related than those in many studies that had shown phonological effects (e.g., Damian & Martin, 1999). As well as the phonologically related noun condition, Experiment 3 included a same noun condition and an unrelated condition. Hence, it replaced the semantically related condition

from Experiment 2 with the phonologically related condition.

Method

Participants

Eighteen students from the University of Edinburgh community were paid to participate as naïve participants. The data from one further student were excluded because of an extremely high proportion of Other responses.

Items

These were the same as Experiment 2, except that some of the items were replaced so that they could be placed in phonologically related pairs. We constructed 36 experimental items consisting of a prime-target pairing (see Appendix). The six conditions differed with respect to whether prime and target contained the same noun, phonologically related nouns, or unrelated nouns, and with respect to whether the pre-nominal or the relative-clause construction was used in the prime. For example, one item consisted of the pairing of (3a–f) with a picture of a pink sheep.

- 3a. The pink sheep (same noun, pre-nominal)
- 3b. The sheep that's pink (same noun, relative clause)
- 3c. The pink ship (phonologically related noun, pre-nominal)
- 3d. The ship that's pink (phonologically related noun, relative clause)
- 3e. The pink ball (unrelated noun, pre-nominal)
- 3f. The ball that's pink (unrelated noun, relative clause)

Hence, the six conditions were defined by the combination of two factors: Phonological Relatedness (same vs. phonologically related vs. unrelated noun) \times Prime Construction (pre-nominal prime vs. relative-clause prime). We constructed six lists of items as in Experiment 2, with a set of 36 filler pairs drawn from the same set (see Appendix).

Procedure

This was the same as Experiment 2, except that the arrangement of the cards was not alphabetical, so that position would not serve as a cue to phonological relationship. Instead we arranged the cards in rough semantic groups, to provide some cue that might be roughly comparable to the effects of alphabetic organization, but which would be unrelated to the critical manipulation.

Results and discussion

There were three Other responses (0.5% of target responses). Proportions of target responses in the different conditions are reported in Fig. 5. Two-way

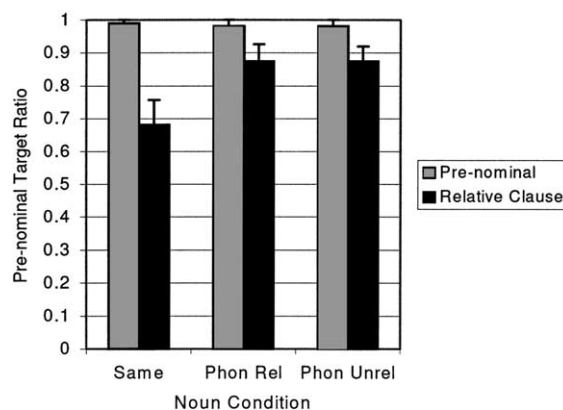


Fig. 5. Pre-nominal target ratios for Experiment 3 across all conditions. Same: same noun (between prime and target); Phon Rel: phonologically related prime noun; Phon Unrel: phonologically unrelated prime noun. Bars represent standard error values.

ANOVAs on the Pre-Nominal Target Ratios for each condition revealed a main effect of Prime Construction ($F(1, 17) = 13.06$, $MSE = .063$, $p < .005$; $F(1, 35) = 85.41$, $MSE = .019$, $p < .001$), with naïve participants being 18% more likely to produce a target utterance with the same construction as the confederate's prime utterance than with the alternative construction. There was also an interaction between Prime Construction and Phonological Relatedness ($F(2, 16) = 8.61$, $MSE = .011$, $p < .005$; $F(2, 34) = 10.59$, $MSE = .021$, $p < .001$), with 31% priming when prime and target used the same noun, 11% priming when prime and target used semantically related nouns, and 11% priming when prime and target used unrelated nouns. Planned comparisons revealed no difference when prime and target nouns were phonologically related versus when they were unrelated (both F s < 1) but did reveal stronger priming when they were the same versus when they were phonologically related ($F(1, 17) = 9.15$, $MSE = .017$, $p < .01$; $F(1, 35) = 18.79$, $MSE = .016$, $p < .01$). When the prime and target were unrelated, the 11% priming was significant (i.e., there was an effect of Construction) ($F(1, 17) = 5.30$, $MSE = .019$, $p < .05$; $F(1, 35) = 1.35$, $MSE = .018$, $p < .01$).

As in Experiments 1 and 2, naïve participants tended to produce target responses of the same syntactic form as the prime, with the magnitude of the effect depending on the relationship between prime and target nouns. There was stronger priming when prime and target nouns were the same versus when they were phonologically related. However, there was no hint of a difference in priming when prime and target nouns were phonologically related versus when they were unrelated. In other words, phonological relationship had no effect on the degree of syntactic priming. These results contrast

strikingly with the clear effect of semantic relationship demonstrated in Experiment 2, though it is important to stress that we have no straightforward way of determining whether the “strength” of the phonological manipulation in this experiment is comparable to the “strength” of the semantic manipulation in Experiment 2 (or even whether such a comparison makes sense at all). Thus the results provide no support for an account in which feedback from the word-form stratum to the lemma stratum affects selection of syntactic form. Such an account predicts enhanced syntactic priming for noun phrases containing phonologically related head nouns.

We should address two reasons why enhanced priming might not have occurred, even if the appropriate type of feedback did occur. First, enhanced priming might have occurred if prime and target nouns had a different kind of phonological relationship. In this experiment, initial and final consonants were repeated, and hence the vowel differed between the nouns. For the majority of our items, prime and target nouns only differed by one phoneme, but a large minority differed by more than one. As it is conceivable that feedback only occurs when prime and target are extremely similar, we re-analyzed the results of Experiment 3 using only the items where the prime and target nouns differed by one phoneme (marked with an asterisk in the appendix), using conservative criteria (e.g., counting diphthongs as two phonemes). For these items, priming was 38% for same noun items, 11% for phonologically related items, and 9% for unrelated items. Importantly, there was no difference between the phonologically related and unrelated conditions (both $F_s < 1$).

It is conceivable that a different kind of phonological relationship is necessary for enhanced priming to occur (e.g., rhyming or overlap of initial consonants and vowel). However, there is no obvious theoretical reason for such types of phonological relationship to be necessary to produce enhanced priming (e.g., the amount of overlap would not in general be greater and therefore there is no reason to expect stronger associations at the word-form level within a framework such as Dell, 1986). Additionally, studies that provide support for feedback in other domains (e.g., lexical access) have used phonological relations similar to ours (e.g., Peterson & Savoy, 1998) or clearly less strong (e.g., Damian & Martin, 1999). So, whereas it is impossible to be certain, there is no reason to suspect that the lack of enhanced priming was due to the specific phonological relationship that we employed.

Second, it is possible that feedback occurs from the word-form to the lemma level, but that it is too weak to affect the magnitude of priming (cf. Dell & O’Searghda, 1991). It is of course impossible to exclude this possibility, but the contrast with Experiment 2 is striking. For this to be the case, the effects of phonology on syntactic encoding

would have to be much weaker than the effects of phonology on word selection, given the evidence for such effects with weaker phonological relationships (e.g., Damian & Martin, 1999). Third, it is possible that facilitatory and inhibitory phonological effects on syntactic encoding have cancelled each other out, given that feedback within our model would predict facilitatory effects, whereas other studies, particularly Bock (1987), found inhibitory effects. However, Bock used a word rather than a syntactic structure to prime syntactic structure, and it is unclear how arguments derived from her proposals could predict inhibition in a situation like ours.

It is important to reiterate that an account in which there are no phonological influences on the selection of syntactic form is not incompatible with accounts that permit phonological effects on lexical access (e.g., Dell, 1986), or with experimental work that supports such accounts (e.g., Damian & Martin, 1999; Ferreira & Griffin, 2003). Finally, note that the prosody of the prime in the same noun conditions [e.g., (3a & b)] and the phonologically related noun conditions [e.g., (3c & d)] were essentially the same. Thus, it is impossible to explain the increased priming effects resulting from lexical repetition in terms of a prosodic representation (cf. Bock & Loebell, 1990).

General discussion

All three experiments demonstrated syntactic priming effects in the production of noun phrases in dialogue. Experiment 1 found that repetition of the head noun between prime and target increased the tendency to repeat syntactic structure. Experiment 2 found an increased tendency toward syntactic repetition when the head nouns in prime and target were semantically related versus when they were unrelated (but less of a tendency than when they were the same). Experiment 3, however, found no tendency toward an increased effect when the head nouns were phonologically related versus when they were unrelated.

These results demonstrate syntactic priming at the level of the noun phrase, in contrast to previous work that has demonstrated syntactic priming based on complete sentences (e.g., Bock, 1986b). The locus of priming is quite different from previous studies that can be interpreted in terms of the priming of one or other argument frame for a verb (e.g., actives vs. passives, prepositional objects vs. direct objects). It also demonstrated that it was possible to prime people into using the relative-clause construction; when the noun and adjective were the same in the prime and target descriptions, 32%, 47%, and 31% of descriptions used a relative-clause construction following a relative-clause prime in Experiments 1, 2, and 3, respectively. Without such priming, the use of the relative clause construction

was rare: When prime and target used different adjectives and nouns, the proportion of relative clause constructions following relative clause primes was 10%, 8%, and 11%; when the prime used the pre-nominal construction, relative clauses were very rarely produced. The overall preference for the pre-nominal construction was presumably because the relative-clause construction is generally rare, at least when the modifier is a single word (cf. *the book that was red* vs. *the book that was red and torn*). The rarity of *the book that was red* probably reflects the fact that *the red book* is a shorter and syntactically less complex alternative with the same meaning. Additionally, there is a tendency to place short phrases early in right-branching languages (Hawkins, 1994; Stallings, MacDonald, & O'Seaghdha, 1998; Wasow, 1997). The fact that these preferences for the pre-nominal construction could be greatly reduced therefore demonstrates the strength of the priming effect resulting from our paradigm.

The results provide support for a model of lexical representation and syntactic encoding based on Levelt et al. (1999) and Pickering and Branigan (1998) (see Fig. 1). In particular, they indicate that syntactic encoding is affected by semantic properties of the head noun. More specifically, they show that information feeds forward from the conceptual stratum to multiple lemmas corresponding to semantically related concepts, and that the members of this set of lemmas are all associated with the appropriate combinatorial node. However, the results provide no evidence for feedback effects from the word-form stratum to the lemma stratum, and hence no evidence that the members of the set of lemmas corresponding to phonologically related word forms are associated with the appropriate combinatorial node.

It may be possible to explain our results in terms of a slightly different account in which lemmas are organized according to semantic factors (e.g., Zorzi & Vigliocco, 1999). On this account, lemmas arise as syntactic features are linked onto semantic representations during language development. It would be straightforward to use this account to predict enhanced priming as a result of semantically related head nouns: Essentially, there would be a stronger link between semantically related than unrelated lemmas, and this link would cause the activation of related lemmas rather than links within the conceptual stratum.

Of course our results can be interpreted in terms of other models of language production. First, they may be compatible with accounts in which syntactic priming is treated as a form of implicit learning (Chang, Dell, Bock, & Griffin, 2000). Second, although they provide no evidence for feedback from phonological processing to syntactic encoding, they are consistent with models in which phonological activation affects word selection (e.g., Dell, 1986). Additionally, they provide no reason to distinguish between cascading and non-cascading

accounts, either within the framework described in Fig. 1 or in alternative models. They may also be compatible with the Interactive Network model, which postulates only one layer of lexical representation (Caramazza, 1997).

Our experiments of course showed syntactic priming effects in dialogue, and therefore are relevant to an understanding of language use in dialogue. Many studies have demonstrated that interlocutors tend to develop the same referring expressions to refer to entities that are relevant to the dialogue. In studies looking at descriptions of abstract shapes (Clark & Wilkes-Gibbs, 1986), objects with multiple possible names (Brennan & Clark, 1996), or positions in a maze (Garrod & Anderson, 1987), interlocutors tend to converge on particular expressions. This literature suggests that this process does not generally involve explicit negotiation. One way such convergence could occur is by largely automatic processes in which interlocutors are primed to produce forms that are equivalent at different levels of representation. We might expect that such automatic alignment would occur at least at the level of lexical repetition.

Our experiments suggest that priming leads to the alignment of referring expressions at a syntactic level as well, with respect to complex expressions where differences in the words are not crucial. Hence, we refer to *entrainment of referring expressions* rather than *lexical entrainment*. The results demonstrate that entrainment of referring expressions is partly due to alignment of syntactic representations, so that interlocutors converge on particular syntactic forms for referring expressions (complex noun phrases). Moreover, they indicate that syntactic priming is stronger when lexical items (head nouns) are repeated. This of course happens in entrainment of referring expressions, where interlocutors attempt to describe the same object, and so regularly use the same head nouns. If they have converged on the same head nouns, then the likelihood of converging on the same syntactic structure will increase as well. Hence, our data help explain why entrainment of referring expressions appears so rapid and essentially automatic.

In this context, the increased priming with semantically related versus unrelated noun phrases is interesting as well, because entrainment of referring expressions appears to be facilitated in the presumably fairly common situation where interlocutors initially use nearly synonymous head nouns as part of a complex expression. Here again, entrainment will be rapid (though not as rapid as if the head nouns are repeated). More generally, these findings support a model where closer relationships at one level (here, the lexical level) lead to closer relationships at other levels (here, the syntactic level) (see Pickering & Garrod, in press). Assuming that such a pattern is general throughout levels of linguistic (and perhaps non-linguistic) representation, we can

begin to understand how interlocutors can rapidly converge on their understanding of a situation, in the sense of having developed aligned situation models (Zwaan & Radvansky, 1998).

Although our experiments are relevant for an understanding of entrainment processes in dialogue, our main findings relate to the understanding of the mechanisms underlying language production in general. Our three experiments showed that speakers were likely to produce noun phrases with the same syntactic structure as the utterance which they had just heard. Additionally, this tendency was strengthened when the head noun was repeated between prime and target, and even when the prime and target head nouns were semantically related. However, there was no increased tendency toward priming when prime and target head nouns were phonologically related. These results are compatible with the model outlined in Fig. 1, with the production of a complex expression leading to the activation of lemmas for words that are semantically related to the words in the expression along with the relevant combinatorial nodes. Although they are not inconsistent with models where phonological activation affects lexical selection, they suggest that phonological activation does not affect syntactic encoding.

Acknowledgments

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Appendix A

Experiment 1 items. The primes are presented in the following order with respect to the target: same color and same shape/same color and different shape/different color and same shape/different color and different shape. The targets are presented after the primes.

1. Red square/red diamond/green square/green diamond. Red square
2. Green diamond/green square/red diamond/red square. Green diamond
3. Blue triangle/blue club/orange triangle/orange club. Blue triangle
4. Orange club/orange triangle/blue club/blue triangle. Orange club
5. Red moon/red ring/brown moon/brown ring. Red moon
6. Brown ring/brown moon/red ring/red moon. Brown ring
7. Black circle/black spade/purple circle/purple spade. Black circle
8. Purple spade/purple circle/black spade/black circle. Purple spade
9. Yellow sun/yellow heart/pink sun/pink heart. Yellow sun
10. Pink heart/pink sun/yellow heart/yellow sun. Pink heart
11. Green rectangle/green oval/blue rectangle/blue oval. Green rectangle
12. Blue oval/blue rectangle/green oval/green rectangle. Blue oval
13. Grey star/grey cross/brown star/brown cross. Grey star
14. Brown cross/brown star/grey cross/grey star. Brown cross
15. Yellow circle/yellow triangle/red circle/red triangle. Yellow circle
16. Red triangle/red circle/yellow triangle/yellow circle. Red triangle
17. Orange arrow/orange moon/pink arrow/pink moon. Orange arrow
18. Pink moon/pink arrow/orange moon/orange arrow. Pink moon
19. Green club/green spade/pink club/pink spade. Green club
20. Pink spade/pink club/green spade/green club. Pink spade
21. Blue sun/blue star/black sun/black star. Blue sun
22. Black star/black sun/blue star/blue sun. Black star
23. Black ring/black oval/purple ring/purple oval. Black ring
24. Purple oval/purple ring/black oval/black ring. Purple oval
25. Orange heart/orange cross/purple heart/purple cross. Orange heart
26. Purple cross/purple heart/orange cross/orange heart. Purple cross
27. Grey square/grey diamond/brown square/brown diamond. Grey square
28. Brown diamond/brown square/grey diamond/grey square. Brown diamond
29. Yellow rectangle/yellow arrow/grey rectangle/grey arrow. Yellow rectangle
30. Grey arrow/grey rectangle/yellow arrow/yellow rectangle. Grey arrow
31. Blue square/blue circle/pink square/pink circle. Blue square
32. Pink circle/pink square/blue circle/blue square. Pink circle
33. Orange diamond/orange sun/purple diamond/purple sun. Orange diamond
34. Purple sun/purple diamond/orange sun/orange diamond. Purple sun
35. Orange rectangle/orange oval/pink rectangle/pink oval. Orange rectangle
36. Pink oval/pink rectangle/orange oval/orange rectangle. Pink oval
37. Black triangle/black heart/grey triangle/grey heart. Black triangle
38. Grey heart/grey triangle/black heart/black triangle. Grey heart
39. Purple club/purple star/red club/red star. Purple club
40. Red star/red club/purple star/purple club. Red star
41. Green ring/green arrow/blue ring/blue arrow. Green ring
42. Blue arrow/blue ring/green arrow/green ring. Blue arrow
43. Black square/black club/yellow square/yellow club. Black square
44. Yellow club/yellow square/black club/black square. Yellow club
45. Grey circle/greyspade/brown circle/brown spade. Grey circle
46. Brown spade/brown circle/grey spade/grey circle. Brown spade

47. Black moon/black rectangle/purple moon/purple rectangle. Black moon
48. Purple rectangle/purple moon/black rectangle/black moon. Purple rectangle

Experiment 2 items. The primes are presented in the following order with respect to the target: same noun/semantically related noun/semantically unrelated noun. The targets are presented after the primes.

1. Red sheep/red goat/red knife. Red sheep
2. Green fork/green knife/green dog. Green fork
3. Pink dog/pink cat/pink skirt. Pink dog
4. Red tiger/red lion/red banjo. Red tiger
5. Green wolf/green fox/green bed. Green wolf
6. Pink shark/pink whale/pink tree. Pink shark
7. Red spider/red beetle/red guitar. Red spider
8. Green watch/green clock/green mop. Green watch
9. Pink star/pink moon/pink fence. Pink star
10. Red tree/red bush/red boot. Red tree
11. Green axe/green saw/green cup. Green axe
12. Pink goose/pink duck/pink dress. Pink goose
13. Red foot/red hand/red bus. Red foot
14. Green shoe/green boot/green cheese. Green shoe
15. Pink glass/pink cup/pink sheep. Pink glass
16. Red leg/red arm/red cap. Red leg
17. Green dress/green skirt/green cat. Green dress
18. Pink brush/pink mop/pink goat. Pink brush
19. Red plate/red bowl/red wolf. Red plate
20. Green train/green bus/green glass. Green train
21. Pink hat/pink cap/pink bush. Pink hat
22. Red cheese/red bread/red fox. Red cheese
23. Green banjo/green guitar/green spider. Green banjo
24. Pink bed/pink cot/pink clock. Pink bed
25. Red fence/red gate/red train. Red fence
26. Green goat/green sheep/green brush. Green goat
27. Pink lion/pink tiger/pink guitar. Pink lion
28. Red whale/red shark/red fork. Red whale
29. Green moon/green star/green cot. Green moon
30. Pink knife/pink fork/pink watch. Pink knife
31. Red duck/red goose/red dress. Red duck
32. Green arm/green leg/green bread. Green arm
33. Pink bus/pink train/pink wolf. Pink bus
34. Red cot/red bed/red glass. Red cot
35. Green cap/green hat/green shark. Green cap
36. Pink bread/pink cheese/pink fox. Pink bread

Experiment 3 items. The primes are presented in the following order with respect to the target: same noun/phonologically related noun/phonologically unrelated noun. The targets are presented after the primes. The asterisk signals items which were used in the re-analysis of Experiment 3.

1. Red bell/red ball/red horse. Red bell*
2. Pink horse/pink house/pink wall. Pink horse
3. Green wall/green well/green cot. Green wall*
4. Red book/red bike/red wheel. Red book
5. Green wheel/green whale/green boot. Green wheel
6. Pink sheep/pink ship/pink ball. Pink sheep*
7. Pink door/pink deer/pink bird. Pink door*
8. Green bone/green bin/green mop. Green bone
9. Pink mop/pink map/pink bear. Pink mop*
10. Red beetle/red bottle/red hammer. Red beetle
11. Green bear/green bar/green hat. Green bear*
12. Pink hat/pink hut/pink bread. Pink hat*

13. Green bed/green bread/green watch. Green bed
14. Red watch/red witch/red bird. Red watch*
15. Pink hammer/pink hamster/pink basket. Pink hammer
16. Green bird/green beard/green cup. Green bird
17. Red bench/red beach/red log. Red bench
18. Pink cup/pink cap/pink beard. Pink cup*
19. Green log/green leg/green bench. Green log*
20. Red basket/red biscuit/red hamster. Red basket*
21. Pink tap/pink tape/pink bell. Pink tap
22. Red gate/red goat/red mine. Red gate*
23. Green moon/green mine/green cat. Green moon*
24. Pink cat/pink cot/pink bike. Pink cat*
25. Red boot/red bat/red ship. Red boot
26. Green ball/green bell/green hut. Green ball*
27. Red well/red wall/red house. Red well*
28. Green bike/green book/green horse. Green bike
29. Pink whale/pink wheel/pink book. Pink whale
30. Red cot/red cat/red whale. Red cot*
31. Pink bat/pink boot/pink well. Pink bat
32. Green ship/green sheep/green bat. Green ship*
33. Green deer/green door/green map. Green deer*
34. Pink bin/pink bone/pink goat. Pink bin
35. Green bottle/green beetle/green hammer. Green bottle
36. Red map/red mop/red sheep. Red map*

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