Syntactic priming in language production

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People have a tendency to repeat the types of sentences they use during language production. Recent experimental work has shown that this phenomenon is at least partly due to 'syntactic priming', whereby the act of processing an utterance with a particular form facilitates processing a subsequent utterance with the same or a related form. In this review, we first provide an overview of the evidence for syntactic priming. The review will then explore the implications of this research for three different areas of language theory: the possible functional significance of syntactic priming in coordinating speakers during dialogue, the mechanisms underlying sentence production, and the nature of linguistic representation.

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Both observational and experimental evidence indicate that people are more likely to use a particular **syntactic** (see Glossary) structure if that structure has recently been employed[1,2]. A good deal of experimental evidence now strongly suggests that this tendency towards **local syntactic consistency** is at least partly the result of **syntactic priming** (sometimes called syntactic persistence or structural priming): the phenomenon whereby the act of processing an utterance with a particular form facilitates processing a subsequent utterance with the same or a related form. We argue that this finding is extremely interesting, because it provides a method that directly taps into syntactic processing. The present review assesses the importance of syntactic priming in language production for different aspects of the cognitive science of language.

Local syntactic consistency and syntactic priming

Good observational evidence for local syntactic consistency can be found in linguistic corpora[3–6]. For example, a study of interviews showed that people tended to use passives more often when they had recently produced another passive[2]. A study of natural conversation highlighted other examples, such as when one speaker said '*But you can go to sleep tonight*' and another responded '*How am I going to sleep tonight?*'[5]. Experimental evidence supports these findings. In one study, shop assistants tended to reply to (the Dutch equivalent of) '*What time do you close?*' and '*At what time do you close?*' with a syntactically congruent answer (e.g. '*Five o'clock*' or '*At five o'clock*')[7]. None of these findings, however, demonstrates syntactic priming. The corpus studies are, by necessity, not controlled for a range of alternative explanations. For example, the tendency to repeat passives might be due to temporary switches to more formal registers at certain points in the interview; whilst both the corpus and experimental studies might actually be showing the well-known facilitatory effects of repeating particular words[8].

However, experimental demonstrations of syntactic priming convincingly rule out most alternative explanations[1,9–16]. In all of these studies, participants are exposed to one or other prime sentence, and its impact on production of a target sentence is measured. The first clear experimental evidence for syntactic priming in production was provided by Bock[1], who found that speakers tended to repeat syntactic form when producing sentences that were not related in meaning and did not form a connected discourse (see Box 1 and Fig. 1). These studies suggest that syntactic priming cannot be explained by **lexical**, **thematic** or **metrical** correspondences between prime and target. In other words, this form of priming appears to be due specifically to the structure of sentences, not the repetition of words, types of event or sound patterns: the syntactic structure of a sentence appears to prime the syntactic structure of a subsequent sentence. Other studies have demonstrated syntactic priming using sentence completion[12,16] (see Fig. 2) and sentence recall[13]. Two reports indicate that it occurs in Dutch[14,15], so the phenomenon is not limited to English. It is also found in both spoken[1,9–11,13–15] and written[12,16] language production. We therefore conclude that syntactic priming does occur. Furthermore, besides being an interesting observation in itself, what is it able to tell us about the way that language is represented and used?

Syntactic priming and coordination in dialogue

Syntactic priming might occur purely as a by-product of syntactic processing, but an alternative is that it serves a functional role. One attractive possibility is that syntactic priming facilitates the use of dialogue. Speakers are faced with the highly complex problem of communicating an idea in a well-formed and fluent utterance, and therefore have to integrate a number of very different kinds of information[17]. Thus, any means of reducing the computational load would be beneficial. Syntactic priming could be a means of reducing the load associated with syntactic processing, by

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Glossary

Active: a sentence such as '*The girl saw the boy*', where the grammatical subject (*the girl*) is typically the instigator of the action denoted by the verb.

Adjunct: adjuncts express information that is not an inherent part of the meaning of the action denoted by a verb. For example, information about location is not inherent to the meaning of *sing*, hence the phrase '*in the bath*' in '*Bob sings in the bath*' is an adjunct of the verb.

Argument: arguments express information that is not an inherent part of the meaning of the action denoted by a verb. For example, the meaning of *put* inherently involves the transition of an object to a new location, hence the phrase '*in the bath*' in '*Bob put the rubber duck in the bath*' is an argument of the verb.

Dative verb: a verb, such as *give*, that is associated with three arguments: the entity that performs the action, the entity that is acted upon, and the entity that is the beneficiary of the action. 'Alternating' dative verbs can appear in two syntactic realizations, one in which the entity that is acted upon precedes the beneficiary of the action (e.g. '*give the book to the girl*'); and one in which the beneficiary of the action precedes the entity that is acted upon (e.g. '*give the girl the book*'). In this review, we call the former the 'prepositional-object form', and the latter the 'double-object form'.

Grammatical function: the grammatical role, such as subject of the verb, that a phrase plays in a sentence.

Grammaticality judgement: a judgement about whether a particular sentence is grammatical or not.

Lemma: the component of a lexical entry that specifies syntactic information. (In some accounts, it also includes semantic information.)

Lexical: relating to words.

Local syntactic consistency: the tendency for syntactic structures to be repeated within sections of a dialogue or text.

Metrical: relating to the rhythmic structure and stress pattern of a sentence.

Morphological: relating to the structure of forms of words. For example, the morphological structure of *cats* distinguishes between the stem *cat* and the inflection *-s* that denotes plural.

Passive: a sentence such as '*The boy was seen by the girl*', where the grammatical subject (*the boy*) is the recipient of the action denoted by the verb.

Phonological: relating to the sound system of a language.

Semantic: relating to meaning.

Syntactic: relating to the grammatical structure of language.

Syntactic priming: (or syntactic persistence, structural priming) the tendency for processing of a particular syntactic construction to increase the ease of subsequently processing of the same or a related syntactic construction. (The term syntactic priming also has another use, concerned with the effects of syntactic context on lexical processing.)

Thematic: relating to the role that an entity plays in an event (e.g. beneficiary of an action).

facilitating production of particular syntactic structures. Listeners, on the other hand, are faced with interpreting syntactically ambiguous utterances. If listeners are sensitive to speakers' tendency towards syntactic priming, then they have a better chance of resolving such ambiguities correctly. Clearly, then, both speakers and listeners would benefit from syntactic priming effects in dialogue, with speakers being primed both by their own prior utterances and those produced by other participants in the dialogue. These effects would result in local syntactic consistency in dialogue: a tendency for participants in a dialogue to produce the same syntactic forms. In other words, participants should tend to coordinate the syntactic structures of their contributions.

Research on the establishment of conventions predicts that speakers in a dialogue will coordinate their language[18]. In keeping with this, there is good evidence for coordination at many levels in dialogue. In describing abstract mazes, participants tend to converge on particular types of description (e.g. descriptions based on paths between positions, or in terms of figures such as T-shapes or protruding limbs) and to use the same words as each other, in the same way[19–21]. This is a form of **semantic** coordination in terms of the mental models employed by the participants. Work on the coordination of referring expressions suggests that participants form a 'conceptual pact' or temporary agreement about how to refer to an object[22–25]. This conceptual pact may gradually develop through a dialogue.

Box 1. Evidence for syntactic priming from picture description

Bock used the guise of a memory test to investigate syntactic priming effects in individual speakers (Ref. a). In her experiments, speakers alternately repeated prime sentences and described semantically unrelated target pictures. Bock manipulated the syntactic forms of the sentences that speakers repeated. For example, the prime sentence might be an active in one condition (e.g. '*One of the fans punched the referee*') and a passive in the other condition (e.g. '*The referee was punched by one of the fans*'). Alternatively, it might employ the prepositional-object form of an alternating **dative verb** in one condition (e.g. '*A rock star sold some cocaine to an undercover agent*') and the double-object form in the other condition (e.g. '*A rock star sold an undercover agent some cocaine*'). The target pictures were designed so that they could be described using either form. Participants showed an increased tendency to produce an active target picture description after an active prime, a passive target picture description after a passive prime, and so on.

Other studies extended these original results. For instance, the production of prepositional-object sentences like '*The secretary took a cake to her boss*' was primed even when prime and target involved different prepositions: thus '*The secretary baked a cake for her boss*' was as effective as '*The secretary took a cake to her boss*' in eliciting '*The girl handed the paintbrush to the man*' (Ref. b). Likewise, sentences containing prepositional phrases that specify locations (e.g. '*The wealthy widow drove her Mercedes to the church*') primed prepositional-object descriptions when the prepositional phrase did not specify a location (e.g. '*A rock star sold some cocaine to an undercover agent*'). Additionally, sentences containing a locative *by*-phrase like '*The foreigner was loitering by the broken traffic light*' primed passive descriptions involving an agentive *by*-phrase. Finally, '*Susan brought a book to study*' did not prime '*The girl gave a brush to the man*', despite their metrical similarities (Ref. c).

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Picture trial (filler)

Picture trial (filler)

Sentence trial (filler)

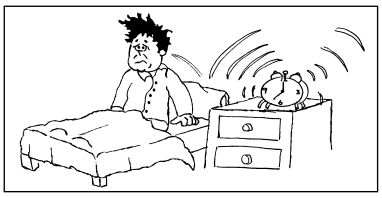
Sentence trial (prime)

Auditory sentence presentation:
'The boat carried five people'

Speaker repeats *'The boat carried five people'*
and makes recognition decision (*'No'*)

Picture trial (target)

Experimenter exposes slide depicting target event:



Speaker describes depicted event (e.g. *'The alarm clock awakened the boy'*)
and makes recognition decision (*'No'*)

Picture trial (filler)

Sentence trial (filler)

Fig. 1. The running recognition paradigm. (Reproduced with permission, from Ref. 11.)

Clearly there are good theoretical grounds for predicting syntactic priming effects between speakers in dialogue, but is there empirical evidence to support this? The corpus evidence reviewed earlier includes demonstrations of local syntactic consistency between speakers in dialogue, but, of course, such studies can be explained without appeals to syntactic priming. There is also some evidence from memory recall experiments that priming for the production of particular syntactic forms can occur as a result of comprehension alone, but these findings relate to individual speakers outside a dialogue[13]. Recent work suggests strongly that syntactic priming does occur between speakers in dialogue when other explanations can be excluded (H. Branigan, M. Pickering and A. Cleland, unpublished data). Pairs of speakers took it in turns to describe pictures to each other that could be described using two forms. One speaker was a confederate of the experimenter who was scripted to produce one or other form as the prime. When the verb remained the same between prime and target, the experimental subject used the same form as the confederate on 77.5% of trials (chance would be 50%); when the verb differed, the percentage was 63%. While preliminary findings, these effects were extremely large, in comparison with data from studies of isolated sentences.

Filler fragment presented: *The boy grumbled...*

Participant completes filler fragment: *...very loudly.*

Prime fragment presented: *The racing driver gave the torn overalls...*

Participant completes prime fragment: *...to the team manager.*

Target fragment presented: *The patient showed...*

Participant completes target fragment: *...his spots to the doctor.*

Filler fragment presented: *The teacher warned the class...*

Participant completes filler fragment: *...to stop misbehaving.*

Fig. 2. The sentence-completion paradigm.

The mechanisms underlying sentence production

Bock and colleagues[1,10,26] argued that producing a sentence involves the activation of procedures associated with producing a particular syntactic form. Thus, there might be a particular procedure associated with producing sentences like '*The teacher gave the book to the boy*' (the prepositional-object form) and another associated with producing sentences like '*The teacher gave the boy the book*' (the double-object form). The activation of a procedure does not disappear immediately, and so subsequent use of that procedure is facilitated. They argued against an alternative explanation of priming, whereby priming is due to an episodic trace or phonological memory of a particular sentence[7]. One obvious problem with this alternative is that the actual prime and target sentences can be very different (e.g. priming occurs when prime and target differ in words and fine-grained syntactic structure[12]).

But the procedural account is problematic if priming occurs from comprehension to production. The procedure associated with comprehending a particular syntactic form must be different from the procedure associated with producing it, because the operation involved is reversed. However, there is another explanation of syntactic priming. The relevant information about syntactic form is the same in both comprehension and production (assuming that there is a rough correspondence between the sentences that people will produce and the sentences that they regard as acceptable sentences of their language). It would therefore be least redundant to represent this information once only, and to draw upon this same body of information in both comprehension and production. (This position may appear natural, but representational assumptions made by theories of language comprehension and theories of language production do not always correspond.) We argue that syntactic priming arises as a result of residual activation of aspects of this representation[27]. Below, we consider the nature of this representation in more detail; but first, we consider the way in which this representation might relate to the rest of the language production system.

We adopt a recent model of lexical representation in language production due to Levelt and colleagues[28]. They assumed a model of language production that comprises stages of 'conceptualization' (generating a message to express), 'formulation' (encoding the message in linguistic form) and 'articulation' (realising the linguistic expression as a series of sounds). Under their account, lexical entries are represented at three levels: a 'conceptual stratum', encoding semantic information, a '**lemma** stratum', encoding syntactic information, and a 'form' stratum, encoding **morphological** and **phonological** information. Roelofs[29,30]

Box 2. Linguistic theory and mental representation

The idea that syntactic priming taps into knowledge of language, and as such can inform theories of syntactic representation, is clearly anathema to those linguists who believe that the domain of linguistics is not that of mental representations (Refs a,b). In their view, linguistics seeks to produce theories of the structural properties of language defined as a collection of sentences, and the sentences of the language themselves constitute the only relevant data. In such accounts, the truth of a linguistic rule cannot be affected by anything that is represented in the mind. Even if this is a reasonable interpretation of one type of linguistics, there must still be a domain of enquiry concerned with understanding knowledge of language, and it is this domain that we are concerned with here.

Thus, most modern linguistics follows Chomsky in assuming that linguistic theory is concerned with human knowledge of language structure and seeks to provide an account of language construed as the mental representation of human linguistic capacities (Ref. c). For example, Chomsky says that 'I would like to think of linguistics as that part of psychology that focuses its attention on one specific cognitive domain and one faculty of mind, the language faculty.' (Ref. d), and that '…evidence derived from psycholinguistic experimentation [and] the study of language use (e.g. processing)…should be relevant, in principle, to determining the properties of…particular grammars' (Ref. e). Evidence from the theoretical difficulty, at least, of acquiring particular grammars is taken seriously in motivating linguistic assumptions (e.g. binary branching; see Ref. f). However, most linguists have, in practice, ignored processing evidence in the design of their theories. In part, this might be the result of disciplinary isolationism, but in part, it might follow from the more reasonable ground that processing theories normally involve assumptions about the nature of the processor as well as assumptions about the representation of language. In sentence comprehension, at least, the great majority of work has not attempted to distinguish between different linguistic assumptions (Ref. g), though there have been exceptions (Refs h,i). Chomsky makes the argument explicitly: 'One common fallacy is to assume that if some experimental result provides counter-evidence to a theory of processing that includes a grammatical theory T and parsing procedure P…, then it is T that is challenged and must be changed. The conclusion is particularly unreasonable in the light of the fact that in general there is independent (so-called 'linguistic') evidence in support of T while there is no reason at all to believe that P is true'. (Ref. e, p. 283, footnote 39.)

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developed a model of the lemma stratum to show how it could represent some syntactic information. His model included 'lemma nodes', which represent the base (i.e. uninflected) form of a word (e.g. *give*), and nodes that represent different types of syntactic information, such as category (e.g. verb).

Pickering and Branigan[12] argued that syntactic priming provides evidence about the organisation of the lemma stratum. Their experiments employed written sentence completion, and varied whether the prime and target shared exactly the same form of the verb (e.g. *gave*), or whether prime and target employed either different forms of the same verb (e.g. *gave* versus *gives*) or different verbs entirely (e.g. *gave* versus *showed*). Their experiments showed that priming was unaffected by whether the prime and target verbs were identical or differed in form (specifically, tense, aspect or number). These results indicate that when people produce sentences like '*The teacher gave the book to the boy*' and '*The racing driver gives the torn overall to the mechanic*', they access the same piece of syntactic information, defining what phrases the verb *give* in all its different forms can combine with. Priming also occurred, though it was reduced, if prime and target employed different verbs. This result indicates that people access the same piece of syntactic information when they produce sentences like '*The teacher gave the book to the boy*' and '*The racing driver showed the torn overall to the mechanic*'. Pickering and Branigan accounted for these effects by proposing an extension of Roelofs' model in which lemma nodes are linked to nodes encoding combinatorial information. They suggested that lemma nodes representing verbs that can be used with a particular syntactic form are directly linked to the same combinatorial node. In other words, base forms of verbs (e.g. *give*, *show*) draw upon shared representations of combinatorial information, in a manner that is not mediated by specific information such as tense.

One of the most important questions for this model relates to the nature of the combinatorial nodes. The findings of Bock and Loebell[10] and Potter and Lombardi[13] indicate that priming takes place in the absence of an overlap in the types of event described in prime and target. They found that sentences containing a *by*-phrase that described a location (e.g. '*The foreigner was loitering by the traffic lights*') primed the production of passive targets containing a *by*-phrase that described the instigator of an action (e.g. '*The boy was stung by the bee*'). These findings suggest that the combinatorial nodes are purely syntactic in nature (rather than mediated by meaning). They also suggest that priming results from the combination of the verb and all the phrases associated with it, rather than the verb and phrases that express intrinsic parts of the verb's meaning. For example, an intrinsic part of *sting*'s meaning is that some entity carried out the action of stinging. In '*The boy was stung by the bee*', this is expressed by the phrase '*by the bee*'. Phrases that express intrinsic parts of a verb's meaning are called **arguments**. In contrast, the meaning of *loiter* does not require specification of a location. Phrases that express non-intrinsic parts of a verb's meaning, like '*by the traffic lights*' in '*The foreigner was loitering by the traffic lights*', are called adjuncts. The finding of priming between sentences involving argument phrases and sentences involving **adjunct** phrases suggests that the combinatorial nodes may not distinguish between adjuncts and arguments. In other words, the combinatorial nodes may specify what phrases a verb combines with, irrespective of those phrases' relationship to the verb.

In addition, Hartsuiker and colleagues[15] found priming effects based upon the order of particular phrases. In their

Box 3. Evidence from syntactic priming against grammatical transformations

Bock, Loebell and Morey (Ref. a) examined syntactic priming for active and passive sentences using the running recognition memory test paradigm (see Box 1). They primed the production of active or passive target descriptions of pictures (e.g. of an alarm clock waking a boy) with an active or a passive prime containing either an animate or an inanimate subject. They found syntactic priming effects: participants produced more actives after an active prime and more passives after a passive prime. But they also found an independent priming effect for **grammatical function** assignment, which was based on animacy: after producing a sentence with an animate subject, participants were more likely to produce another sentence with an animate subject. For example, an animate subject in an active sentence primed an animate subject in a passive sentence. The interesting linguistic point in these cases is that the binding that was primed was the binding between the property of animacy and the subject of the sentence that was actually produced. In other words, speakers categorized together the subject of an active sentence and the subject of a passive sentence. These findings argue against 'relation-changing' theories of linguistics, in which the subject of a passive sentence is treated in the same way as the object of an active sentence (Refs b–d). Instead, they provide evidence for theories of grammar in which the role of transformations is reduced (Ref. e) or eliminated (Refs f,g).

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experiments, the two alternative syntactic forms involved the same phrases combined in different orders. For example, participants might say '*On the table is the ball*' or '*The ball is on the table*', where the locative phrase ('*on the table*') appears before the verb and the subject (*the ball*) appears after the verb, or vice versa. Their results suggest that at least one component of syntactic priming may be related to the order of phrases; this ordering information might be encoded into the combinatorial nodes.

The evidence of syntactic priming in dialogue suggests further that the combinatorial nodes are shared between production and comprehension. As such, it provides good evidence for Levelt and colleagues' proposal that the lemma stratum is common to both comprehension and production[28]. This claim is striking, because theories of language comprehension do not normally incorporate a lemma stratum.

Syntactic priming and knowledge of language

We have argued that syntactic priming is informative about a lemma stratum that is common to both comprehension and production, and that priming works by activating knowledge that is stored at this level. We therefore claim that syntactic priming taps into knowledge of language itself, and as such can inform linguistic theories that are concerned with accounting for knowledge of language[27] (see Box 2). Chomsky argues that evidence from language processing is not informative about knowledge of language, essentially because any pattern of processing data (e.g. reaction times) is compatible with one grammar combined with one set of processing assumptions, or a different grammar combined with a different set of processing assumptions[31]. Instead he favours the use of 'linguistic' evidence, most notably **grammaticality judgements**. The problem with his argument is that grammaticality judgements are themselves the product of language processing.

We argue that syntactic priming is less affected by Chomsky's criticisms than grammaticality judgements. First, participants are generally unaware of the priming manipulations or the purpose of the investigation[1] and therefore the task provides evidence about mental representation without engaging explicit or conscious strategies. Conscious strategies, as employed in making grammaticality judgements, are obviously prone to bias. More fundamentally, however, grammaticality judgements provide direct evidence only about whether a sentence forms part of a language. They cannot provide direct evidence of which sentences are syntactically related. In contrast, syntactic priming arises from the language processor recognizing a syntactic relationship between two sentences. Thus syntactic priming is directly informative about syntactic categorization. Furthermore, because it is purely dependent on categorization, the inference from syntactic priming to theory of syntax is independent of particular assumptions about processing. (Explicit judgements of similarity, in contrast, may reflect non-syntactic similarities.)

We therefore claim that results from experiments about syntactic priming allow us to draw inferences about knowledge of language. For example, the finding that prepositional-object sentences prime other prepositional-object sentences, whereas double-object sentences prime other double-object sentences, with other sources of the priming being excluded,[1,9,12] suggests that people's knowledge of language represents a distinction between these two types of sentence; and the finding that syntactic priming occurs

Outstanding questions

- What is the precise nature of the linguistic representations that can be primed? Do they correspond to the representations assumed by a particular approach to syntax?
- In what sense is syntactic priming a kind of implicit learning?
- To what extent is priming affected by the nature of the communicative situation? Is it an automatic process that occurs irrespective of the situation, or is it more strategic, with producers being primed more if the previous utterances are in some sense more relevant to them?
- Can priming be informative about the stages that the processor goes through in the production of utterances?
- Which, if any, other levels of linguistic representation can be primed? Are there, for example, abstract levels of semantic representation that may be primed?
- Can priming be informative about the representations employed by diverse groups of language users, such as children, second-language learners, and various kinds of aphasics?

between sentences describing different types of event[10] suggests that people's mental grammars contain a syntactic component that is unencumbered with information about the type of event described. Future studies may be able to determine precisely what primes what, thereby specifying the nature of syntactic knowledge in more detail.

One experiment that illustrates this potential was conducted by Bock and colleagues[11]. Using the running recognition paradigm shown in Fig. 1, they found evidence that speakers treat the subjects of **active** and **passive** sentences alike (see Box 3). This finding supports linguistic theories which provide the same account of subjects in active and passive sentences and which do not treat passive sentences as 'transformed' versions of active sentences[32–34].

Conclusions

Syntactic priming is clearly of considerable interest in its own right. However, we believe that it can be employed as a method that will allow us to appreciate the intricacies of syntactic representation and processing, just as, for example, semantic priming has allowed researchers to understand much about lexical–semantic representation[35]. In contrast to work on semantic priming, however, there have only been a handful of studies on syntactic priming. The area is ready for a great deal of further exploration.

For example, there has been very little attempt to apply syntactic priming to the study of any population apart from normal adults. One recent study has looked at syntactic priming in Broca's aphasics[36], and found, perhaps surprisingly, strong priming even when other aspects of language production were severely impaired. This suggests that such patients often retain knowledge of language, though they are not always able to use it appropriately. It also lends support to the claim that syntactic priming is largely an automatic, implicit process. A similar claim has been made about semantic and lexical coordination in young children's dialogue[20]. Priming might therefore be very effective in young children and those less practised in language use. If so, skilled language-users might be less susceptible to syntactic priming, because they have more computational resources available and hence are much more active about developing their communicative goals in syntactic detail. However, this is a question for further research.

This review has explored the importance of research on syntactic priming for theories of dialogue, accounts of the mechanisms underlying language production, and the nature of linguistic representation. It should be apparent that it has much to offer to all of these areas.

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