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Activation of Syntactic Information During Language Production

Martin J. Pickering,[1,3] Holly P. Branigan,[1] Alexandra A. Cleland,[1] and Andrew J. Stewart[2]

In order to produce utterances, people must draw upon syntactic information. This paper considers how evidence from syntactic priming experiments casts light upon the nature of syntactic information activation during language production. We examine three issues: the way in which syntactic information is initially activated, the circumstances under which activation may persist or dissipate, and the effects of residual activation of syntactic information on subsequent language production. Evidence from dialog experiments suggests that the information that is initially activated is the same in both production and comprehension. Evidence about the persistence of activation following initial activation is more complex. We suggest that persistence may be related to the potential relevance of the information for subsequent syntactic processing. We show that current evidence is inconclusive about how long syntactic information remains activated.

Observational evidence demonstrates that people have a tendency to repeat syntactic structure (Schenkein, 1980; Tannen, 1989; Weiner & Labov, 1983). Following the classic work of Bock (1986), a large number of studies have shown that similar effects can be demonstrated in controlled experiments and that nonsyntactic (e.g., lexical, semantic, prosodic) explanations of the results can be discounted. Thus the phenomenon is known as *syntactic priming* (or

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[1] Human Communication Research Centre, University of Glasgow, Glasgow, Wales, Bangor, U.K.

[2] Department of Psychology, University of Edinburgh, 7 George Square, Edinburgh EH, U.K.

[3] Author to whom all correspondence should be sent. Email: martin@psy.gla.ac.uk.

[4] Terminology is tricky here, unfortunately. Syntactic priming also refers to another phenomenon: facilitation in lexical processing following an appropriate syntactic context (e.g., Wright & Garrett, 1984). We retain the term because *syntactic persistence* may be too limited (for instance, people may find production of a particular structure is faster following a previous example of that structure) and *structural priming* assumes that the locus of priming is that aspect of syntax that is concerned with tree structures or their equivalent. In the context of language production, the term syntactic priming should not be ambiguous.

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syntactic persistence or *structural priming*).[4] In Bock's paradigm, participants repeated sentences and described pictures under the guise of a memory test and the syntax of the picture descriptions tended to mirror that of the previous sentence (Bock, 1986, 1989; Bock, Dell, Griffin, Chang & Ferreira, 1996; Bock & Loebell, 1990; Bock, Loebell & Morey, 1992; Hartsuiker & Kolk, 1998; Hartsuiker, Kolk, & Huiskamp, 1999). Potter and Lombardi (1998) demonstrated priming in sentence recall. We have found priming in written sentence completion (Branigan, Pickering, & Cleland, in press; Branigan, Stewart, & Pickering, 1998; Pickering & Branigan, 1998), as well as two new methods: spoken sentence completion (Branigan, Pickering, & Stewart, 1999) and confederate-scripting in dialogue (Branigan, Pickering, & Cleland, 1999). See Pickering and Branigan (1999) for a recent review of the data.

We hypothesize that syntactic priming is due to the residual activation of information or procedures that can be likened to syntactic rules. Under one account, syntactic procedures that have been previously employed in producing an utterance are more likely to be used in subsequent production (Bock & Loebell, 1990). Under an alternative account, syntactic information that has been previously accessed in processing an utterance is easier to access during subsequent processing (Branigan, Pickering, Liversedge, Stewart & Urbach, 1995). In Branigan *et al.*, we argued that syntactic priming effects can be informative about the nature of syntactic representation. In this paper, our focus is on the question of what they can say about the way in which syntactic information is accessed and utilized. We first consider initial activation and discuss evidence that syntactic priming occurs between speakers in dialog, which suggests that the same rules are activated during comprehension and production. We then consider what evidence from syntactic priming can tell us about whether activation subsequently persists or dissipates. We propose that persistence of activation may have functional benefits, but there are some circumstances in which this persistence of activation may be undesirable. In accord with this, we discuss evidence about circumstances under which activation does not persist. Finally, we discuss the relationship between the residual activation of syntactic information and subsequent syntactic processing.

INITIAL ACTIVATION OF RULES

We assume that producing an utterance involves accessing information about possible (i.e., licensed) syntactic structures and that this information is encoded as syntactic rules. How are such rules initially activated?

Pickering and Branigan (1998) suggested that initial activation of rules is linked to the process of lemma selection. Roelofs (1992, 1993) and Levelt,

Roelofs, and Meyer (1999) proposed a model of the representation of linguistic information in the production lexicon, in which a lemma stratum encodes syntactic information. They did not provide much detail about the internal structure of this stratum, but Pickering and Branigan (1998) extended their model to account for the representation of categorial information (e.g., verb), featural information (e.g., plural), and combinatorial information about how verbs, for instance, combine with other linguistic units to form possible expressions of the language. For example, a verb like *give* can appear with two NPs, yielding a double object (DO) structure (e.g., *the girl gave the boy a book*), or with an NP and a PP, yielding a prepositional object (PO) structure (e.g., *the girl gave a book to the boy*). In Pickering and Branigan's model, the syntactic rules that license these two structures are encoded via combinatorial nodes. The rule (or rules) that licenses a DO structure is encoded via the NP,NP combinatorial node and the rule that licenses a PO structure is encoded via the NP,PP combinatorial node. Any verb that can appear in a DO structure is linked to the NP,NP combinatorial node and any verb that can appear in a PO structure is linked to the NP,PP combinatorial node. When a lemma node is selected, a relevant combinatorial node is also selected. For example, when the lemma node for *give* is selected, either the NP,NP combinatorial node or the NP,PP combinatorial node is selected as well. If the NP,NP node is selected, construction of a DO structure is licensed; if the NP,PP node is selected, construction of a PO structure is licensed. In this way, a rule is selected (hence, activated) when a lemma is selected. We assume that these licensing rules are context free. That is, the same rule (encoded in the same combinatorial node) is implicated in the production of, for example, a PO structure, irrespective of the syntactic context in which that structure appears.

Pickering and Branigan (1998) suggested that syntactic priming occurs when activation of a combinatorial node does not decay immediately. For example, prior use of a verb in a PO construction involves activation of the NP,PP combinatorial node. If this node retains residual activation, it is more likely to be selected during subsequent processing. Because syntactic priming effects arise from residual activation, they are informative about the circumstances under which initial activation (which gives rise to residual activation) occurs. Pickering and Branigan conducted a series of experiments in which they manipulated whether prime and target shared exactly the same form of the verb, whether they employed different forms of the same verb (e.g., *gave* vs. *gives*), or whether they employed different verbs (e.g., *gave* vs. *sent*). Priming was unaffected by variations in the form of the verb. Hence, the same syntactic rule is activated during production of sentences that differ with respect to featural information. Furthermore, priming occurred between sentences involving different verbs (although it was reduced in these cases).

The finding of priming between sentences involving different verbs suggests that the same syntactic information is activated whenever a particular construction is produced, irrespective of the identity of the verb. Hence, although a rule is activated with respect to a specific verb (when that verb's lemma is selected), the rule that is activated is shared between all verbs that can appear in that construction. Overall, these results suggest that the initial activation of a syntactic rule (via an associated combinatorial node) is linked to the selection of any verb that can appear in the construction licensed by that rule, irrespective of the precise form of that verb.

An important question concerns whether the initial activation of syntactic rules is specific to production or comprehension. That is, can the same rule be activated during comprehension of a particular structure as during production of that structure? Levelt *et al.* (1999) suggested that the lemma stratum and, hence, the syntactic information encoded there, is shared between production and comprehension, such that the comprehension and production systems draw upon the same store of syntactic information. Under Pickering and Branigan's (1998) account of syntactic priming, the same combinatorial node is therefore activated during comprehension of a PO structure as during production of a PO structure. Thus, their model predicts that initial activation of a syntactic rule during comprehension of a structure could result in a greater likelihood of its being retrieved during subsequent production. In other words, their account predicts that syntactic priming should occur between comprehension and production if it occurs between production and production.

Branigan, Pickering, and Cleland (1999) found evidence that priming does take place between comprehension and production during natural dialog, using what they termed a *confederate-scripting* technique. Pairs of participants played a dialog game in which they alternated between describing a picture to their partner and selecting a picture that matched their partner's description. In fact, only one participant was an experimental subject; the other was actually a confederate of the experimenter who was scripted to produce particular responses. For example, the confederate was scripted to describe a picture of a pirate showing a monk a book either as *the pirate showing the monk the book* (a DO description) or as *the pirate showing the book to the monk* (a PO description).

Branigan, Pickering, and Cleland (1999) found that the form of the confederate's description affected the form of the subject's subsequent description for an unrelated picture (e.g., a cowboy offering a boxer an apple). This effect was very large and occurred whether the prime and target employed the same or a different verb, although, as in Pickering and Branigan (1998), the effect was reduced if the verbs differed. These results suggest that participants coordinate the syntactic structure of their contributions in dialog,

just as they do the lexical and semantic content of their contributions (e.g., Brennan & Clark, 1996; Garrod & Anderson, 1987). More importantly for present purposes, the results indicate that the same syntactic information is activated during production of a particular syntactic structure as during comprehension of that structure and that this occurs during natural dialog. The finding of syntactic priming from comprehension to production of a particular structure also provides good support for the existence of a lemma stratum that encodes syntactic information and that is shared between production and comprehension (see also Potter & Lombardi, 1998).

Note that the results from dialog also argue against Bock and Loebell's (1990) account of syntactic priming. Bock and Loebell suggested that priming arises from the residual activation of procedures associated with the act of production. Their account naturally predicts priming from production to production, but not from comprehension to production, because the procedures associated with comprehending a particular syntactic form must be different from the procedures associated with producing that form, as the operation involved is reversed. The finding that priming occurs from comprehension to production instead supports an information-based account of priming. It is, however, possible that some (but not all) of the procedures are common to production and comprehension; if so, Bock and Loebell would predict some priming from comprehension to production, but a greater magnitude from production to production. However, the fact that Branigan, Pickering, and Cleland (1999) found such strong priming from comprehension to production in dialog makes such an account unlikely.

DOES PERSISTENCE OF ACTIVATION ALWAYS OCCUR?

We have argued that syntactic priming effects provide evidence about the way in which syntactic information is initially activated. They also provide good evidence about the circumstances under which activation of that information may persist, in particular whether a syntactic rule always retains some activation following use, or whether there are circumstances under which activation immediately disappears.

We assume that in a sentence involving more than one verb, the syntactic rule associated with the verb that appears in the earliest linear position is selected first, then the syntactic rule associated with the verb in the next linear position, and so on, under the assumption of incremental production. In such circumstances, what determines whether the activation of each rule persists or dissipates?

We can identify two possibilities. Under the first alternative, the persistence of activation of rules is related to the linear position of their associated

verbs in the utterance. Assuming that the activation decays in a way that is at least partly related to the passage of time, the rules associated with earlier verbs in an utterance would be less activated following production of the utterance than the rule associated with the final verb. We term this a *linear model* of syntactic activation. Under the second alternative, the persistence of activation of rules is related to the hierarchical structure of the utterance, more specifically, the status of the clause in which the verb associated with each rule appears. We term this a *hierarchical model* of syntactic activation. This model is plausible because the relevance of syntactic information to subsequent processing depends in part upon the hierarchical status of the clause with which it is associated. A matrix clause is—by definition—the overarching clause, which structurally contains any embedded clauses. Assuming that clauses must be nested, the matrix clause can begin again after an embedded clause. Thus matrix clause structure is always potentially relevant to subsequent processing. For example, after producing *Mary said that she was hurt,* a speaker can continue the matrix clause with *in a faint voice.* In contrast, embedded clause structure cannot be subsequently resumed and is relevant only within the embedded clause itself.

Hence, we can see why the activation of syntactic rules associated with main verbs might persist after the activation of rules associated with subsequent subordinate verbs has disappeared. Thus the rule associated with the embedded verb in an utterance would be less activated following production of the utterance than the rule associated with the main verb, even if the embedded verb is the most recent verb. This account predicts effects associated with some clause boundaries to occur in syntactic priming. It is consistent with findings suggesting that sentences are planned, at least to some extent, on a clause-by-clause basis (Bock & Cutting, 1992; Ford, 1982), and with hierarchical accounts of production more generally (e.g., Dell, Burger, & Svec, 1997; Vigliocco & Nicol, 1998).

Note that the hierarchical account fits with a functional explanation of syntactic priming whereby it reduces the speaker's computational load (Branigan, Pickering, & Cleland, 1999; Pickering & Branigan, 1999). The claim is that residual activation of syntactic rules helps the speaker choose a syntactic structure for his or her utterance, by reducing the amount of additional activation that is necessary to select a rule. However, in some circumstances, residual activation might be disadvantageous, because uncontrolled residual activation of one syntactic rule could interfere when the speaker has to select another rule. For example, residual activation of the rule associated with the PO structure could cause interference when the verb that has been selected is one that only allows an intransitive structure. Under the hierarchical account, this danger is minimized by ensuring that only information that might be relevant to subsequent processing retains activa-

tion. In this way, a trade-off is established between the residual activation of syntactic information when this offers functional benefit, and immediate dissipation of activation when residual activation might well be functionally disadvantageous.

Of course, priming could, in principle, occur between an embedded clause and a subsequent sentence even when it does not occur between an embedded clause and the main clause in the same sentence. However, we assume that a node is either activated or not. If it is activated, then it can affect any future syntactic processing, whether within the same sentence or not. The processor is able to vary the activation of a node. It is not able to limit the effects of any activation to a particular syntactic environment. Because the hierarachical account predicts no priming from an embedded clause to a main clause within a sentence, it predicts no priming from an embedded clause to a main clause in the subsequent sentence.

Branigan, Pickering, and Stewart (1999) used syntactic priming effects to distinguish between the hierarchical and linear models by having subjects provide spoken completions for fragments like (1) and (2):

(1) Anne claimed that the racing driver showed the torn overall . . .
(2) As Anne claimed, the racing driver showed the torn overall . . .

The final clause differs in hierarchical status between (1) and (2). In (1), it is an embedded clause, but in (2), it is a main clause. Participants tended to produce PO completions for both fragments (e.g., *to the mechanic*). The two accounts of syntactic activation outlined above make different predictions about the effects that producing a PO completion should have on subsequent production. According to the linear account, *show* is the most recently encountered verb in both cases and so the PO rule associated with *show* should retain activation following both (1) and (2). Hence, speakers should tend to produce more PO structures in both cases than following a DO prime. According to the hierarchical account, however, *show* is the main verb in the (2) but not in (1). Hence, the PO rule selected in association with *show* should retain activation after (2) is completed, but not after (1). Speakers should, therefore, tend to produce more PO structures in (2) than after producing a DO sentence like *As Anne claimed, the racing driver showed the young mechanic the overall,* but there should be no comparable priming effect in (1).

The results supported the hierarchical model: There was strong and reliable priming when the relevant syntactic rule was associated with the main verb, but no priming when the rule was associated with an embedded verb. These results suggest that the syntactic rules do not always retain activation immediately following initial activation and that the persistence of rule activation is sensitive to hierarchical structure.

HOW DOES RESIDUAL ACTIVATION AFFECT SUBSEQUENT PROCESSING?

Clearly, the very existence of syntactic priming effects in production shows that residual activation affects subsequent processing in some way. Most work on syntactic priming has concentrated on cases of immediate priming, where no material intervenes between prime and target. Thus a number of experiments have presented evidence that the likelihood of producing a particular syntactic structure is affected by an immediately prior utterance. This effect may be extremely strong in some circumstances: Experiments have found that syntactic priming can increase the likelihood of producing a particular structure by as much as 26% in dialog (Branigan, Pickering & Cleland, 1999) and 23% in individual speakers (Bock, 1986: Experiment 1). There is also some evidence that prior production of a particular syntactic structure speeds subsequent production of the same structure (Smith & Wheeldon, 1999).

A different issue concerns the nature of this persistence: how long it persists for, and what causes it to decay eventually. The standard priming design involves two construction types (passives and actives, or PO and DO forms) that are presented repeatedly within a single experiment. The priming effect is measured with respect to an immediately preceding trial. In most experiments, the effect of earlier trials upon the current trial is not considered. This seems to be a reasonable approach, because results show that subjects' behavior is reliably influenced by an immediately preceding prime. Such results demonstrate that priming from earlier trials can be overridden by subsequent information. In other words, priming must disappear over time under at least some conditions. In terms of information activation, this means that activation of a syntactic rule does not persist permanently following initial activation.

There are two ways in which activation might dissipate. One possibility is that activation decays purely as a function of time. In that case, the more recently activated a rule, the stronger its level of activation and, hence, the greater the likelihood of priming. A different possibility is that decay is linked to the activation of other syntactic rules. (It is an open question whether or not this is due to actual process of inhibition.) This, in turn, might be a general effect, whereby the activation of any other rule is associated with decay; or it might alternatively be a competitive effect. For example, activation might persist until another rule that can be used to express the same message is activated.

We now turn to the question of whether priming is long lasting. Under the activation model, syntactic priming arises from the repeated use of the same syntactic rule; in other words it is repetition priming effect. Hence we

might expect it to be relatively long lasting, like other repetition priming effects (Wheeldon & Monsell, 1992). Evidence for long-term priming and, hence, that activation of a syntactic rule can persist over long periods of time, is somewhat mixed. Levelt and Kelter (1982) found that when asked *What time do you close?* (in Dutch), shop assistants tended to say *Five o'clock;* but when asked *At what time do you close?*, they tended to say *At five o'clock.* However, when the question was followed by another clause and a tag question (*because I have to come in specially, do you see*), this tendency disappeared. Priming in this experiment might have a lexical source, so it might not serve as evidence against the persistence of syntactic priming. It also involved priming between comprehension and production in a very particular kind of environment (question answering). Bock *et al.* (1996) reported priming that lasted over as many as ten intervening trials in the picture–description paradigm. However, Branigan *et al.* (in press) found reliable priming using written sentence completion (with the same verb) only if the prime and the target were adjacent. When one fragment intervened between prime and target, there was a weak tendency toward priming and, when four fragments intervened, evidence for priming disappeared entirely. It is not clear what difference between the studies caused the discrepancy in Bock *et al.*'s and Branigan *et al.*'s results. We can discount repetition of the verb in Branigan *et al.*, because that should increase rather than decrease priming effects (Pickering & Branigan, 1998). It may be related to the fact that Bock *et al.*'s task emphasizes memory for sentence form, the slower speed of writing compared with speech, or the fact that participants tended to write more in the completion task than occurred in Bock *et al.*'s repetition task. Alternatively, the completion task may emphasize conceptual-level processing, as participants have to generate a state of affairs that they wish to communicate, unlike picture description. Whatever the cause of the differences, Branigan *et al.*'s (in press) results cast some light on the factors that lead to decay of activation. In their experiment, the intervening fragments were intransitive structures that could not express the same message as the primed PO and DO structures. Hence, their findings suggest that the decay in activation of a syntactic rule is not associated uniquely with the activation of a competing rule. Hartsuiker and Kolk (1998) examined possible temporal influences on decay of activation. They found no evidence that priming was influenced by a temporal delay between prime and target; but they compared no delay with a 1 s delay and this may have been too small a difference to be of importance.

A slightly different issue is whether the activation of a rule is greater and persists longer the more often that rule has been employed. In other words, does multiple use of a rule increase the extent and persistence of priming effects? Pickering and Branigan (1998) found numerically much

larger priming effects with two different-verb primes than in another experiment with one different-verb prime. Although no formal comparison between the experiments is possible, the difference does suggest that multiple primes can sometimes have a larger effect than a single prime. This, in turn, suggests that priming from a nonadjacent prime does occur and, moreover, that the activation from each instance of a structure may be additive. Boyland and Anderson (1998) found long-term priming effects with multiple primes: After producing multiple sentences with a particular structure in an initial session, participants were more likely to produce the same structure in a subsequent session 20 min later. Hartsuiker and Kolk (1998) measured the proportion of PO and DO constructions that participants produced at the beginning of an experimental session (including two word-order variants of the PO construction that are permissible in Dutch). Participants were then presented with repeated priming trials. Apart from the usual short-term priming effect, Hartsuiker and Kolk also found that the overall proportion of both PO and DO sentences went up (compared with other responses). They suggested that the repeated production of PO and DO sentences through the course of the experiment gave rise to a cumulative priming effect. However, an alternative explanation for their results is that priming was also taking place at a conceptual level of representation: Participants were primed to produce sentences with three-argument verbs (other responses typically did not have three arguments). Taken together, all these results are compatible with the hypothesis that multiple application of a rule can lead to greater and more persistent activation, resulting in long-term priming effects.

One interesting hypothesis that has been proposed on the basis of such findings is that the increased likelihood of producing a particular structure following multiple applications of the relevant rule is in some way linked to implicit learning (e.g., Chang, Dell, Bock & Griffin, 1999). One way in which this approach could be realized within the lemma activation model proposed by Pickering and Branigan (1998) would be if repeated application of a rule altered the weight of the link between a lemma and a combinatorial node. The effect would be to increase the amount of activation passed to that combinatorial node when a lemma linked to it was selected, which would, in turn, raise the combinatorial node's likelihood of selection. In that case, application of a particular rule would not only involve activation of that rule and under at least some circumstances, subsequent persistence of that activation; it would also involve changing the extent to which that rule receives activation in subsequent processing. Hence, syntactic priming experiments might not only be informative about when syntactic information is activated, but they might also be informative about the degree to which that information initially receives activation. This remains a promising area for future research.

CONCLUSION

Syntactic priming experiments have proved themselves to be a valuable source of information about syntactic representation and processing. In this paper, we have argued that they are informative about the way in which the activation of syntactic information is initially triggered and may subsequently persist. We suggest that they offer evidence for future work employing an activation-based approach to language production.

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