Language and Linguistics Compass 4/10 (2010): 925–937, 10.1111/j.1749-818x.2010.00249.x

Syntactic Priming Effects in Comprehension: A Critical Review

Kristen M. Tooley[1]* and Matthew J. Traxler[2]
[1]*University of Illinois, Urbana-Champaign and* [2]*University of California, Davis*

Abstract

Syntactic priming occurs when processing of a target sentence is facilitated following processing of a prime sentence that has the same syntactic structure (Bock, 1986 *Cognitive Psychology*, 18. 355–387). Syntactic priming has been widely investigated in production (Bock, 1986 *Cognitive Psychology*, 18. 355–387; Bock and Griffin, 2000 *General*. 129(2). 177–192; Cleland and Pickering, 2003. *Journal of Memory and Language*, 49. 214–230; Cleland and Pickering 2006. *Journal of Memory and Language*, 54. 185–198; Pickering and Branigan, 1998. *Journal of Memory and Language*, 39. 633–651; and others), but only relatively recently in comprehension (Arai et al. 2007. *Cognitive Psychology*, 54(3). 218–250; Ledoux et al., 2007. *Psychological Science*. 18(2). 135–143; and others). This article reviews the current literature on syntactic priming in comprehension and contrasts these findings to those in production. Critically, syntactic priming effects in comprehension are observed more often when prime and target sentences share a content word, whereas in production, these effects are often observed when there are no shared content words between the primes and targets. Possible explanations for the differing degrees of lexical dependency between syntactic priming effects in production and in comprehension are posed and include differences in task paradigms and stimuli, differences in time course and syntactic processing between the two modalities, and mechanistic differences. Implications from the reviewed literature are then considered in attempts at determining the most likely mechanistic explanation for syntactic priming effects in both comprehension and production. A residual activation account (Pickering and Branigan, 1998. *Journal of Memory and Language*, 39. 633–651), an implicit learning account (Bock and Griffin, 2000 *General*. 129(2). 177–192; Chang et al. 2006. *Psychological Review*, 113(2). 234–272), and a dual mechanism account (Tooley, 2009. Is Syntactic Priming in Sentence Comprehension Really Just Implicit Learning? Paper presented to the *22nd Annual CUNY Conference on Human Sentence Processing*, Davis, March 26–28) are outlined. The dual mechanism account may prove more consistent with a wider range of the reviewed research findings.

> The greater part of the world's troubles are due to questions of grammar.
>
> Michel de Montaign

Syntactic Priming

Grammar provides components of structure to language, allowing us to impart meaning based on the order and combination of words that we use. Language researchers have long studied how grammatical knowledge is represented and used during language processing. Recent research on *syntactic priming* is contributing to an improved understanding of syntactic processes in general, as well as addressing issues of how syntax is acquired and represented. Syntactic priming effects reflect facilitated processing of a target sentence's syntactic structure, following processing of a prime sentence that has the same syntactic

structure (Bock 1986). For the purposes of this paper, the modality of the priming effect will be identified by the modality of the target sentence (e.g. producing a target sentence versus comprehending a target sentence). One real-world example of how this phenomenon takes places comes from Levelt and Kelter (1982), who telephoned shop owners and asked them (in Dutch) either 'what time does your shop close?' or 'at what time does your shop close'. With remarkable consistency, the shop owners who were asked the latter structured their responses in a prepositional phrase (e.g. 'at 6 PM'), whereas the shop owners who were asked the former did not (e.g. '6 PM'). Though these shop owners could have structured their answers in either way, merely having comprehended a prepositional phrase ('at what time') in the question primed them to include a prepositional phrase (or not) in their answers.

Syntactic priming (also termed 'structural priming' or 'structural persistence') has been extensively studied in language production, beginning with J.K. Bock's classic study in 1986. In this set of experiments, participants were asked to repeat sentences and describe simple pictures, with the assumption that their memories for these items would later be tested. When participants repeated a prime sentence with a particular structure, they were more likely to then describe a subsequent picture using that structure (versus when they were primed with a plausible alternative structure). For example, if they had just repeated the prepositional object (PO) sentence 'the governess made a pot of tea for the princess', they would be more likely to describe a subsequent picture of a girl reading a story to an elderly woman using a PO structure 'the girl read the story to the old woman' as opposed to when they had just repeated (been primed with) a double object (DO) structure 'the governess made the princess a pot of tea'. This same trend was observed for active versus passive sentences ('the girl is kicking the boy' vs. 'the boy was kicked by the girl'). Importantly, these priming effects were observed when there were no shared content words between the prime sentences and the pictures being described. These results suggest that syntactic structure can be 'primed' in a similar fashion to how particular words or word meanings are primed in lexical/semantic priming paradigms (Neely 1977), which in turn supports the notion that we store abstract structural representations for the syntactic structures that we use.

Since Bock's original study, syntactic priming has been studied extensively in language production, and similar results have been observed for a variety of different linguistic situations (Bock and Loebell 1990; Bock and Griffin 2000; Branigan et al. 2000a,b; Corley and Scheepers 2002; Cleland and Pickering 2003, 2006). Syntactic priming occurs across speakers in conversation tasks, (Branigan et al. 2000a,b), in both written and spoken forms of language production (Pickering and Branigan 1998), in English (Bock 1986; and others), German (e.g. Scheepers 2003), Dutch (e.g. Hartsuiker and Kolk 1998b), Spanish (e.g. Hartsuiker et al. 2004), Korean (Shin and Christianson 2009), and cross-linguistically in bilinguals (e.g. Loebell and Bock 2003; Meijer and Fox Tree 2003; Hartsuiker et al. 2004; Weber and Indefrey 2009). Syntactic priming effects have been observed in 4- to 6- year-old children (Savage et al. 2003; Huttenlocher et al. 2004) and in analyses of natural speech corpora (Gries 2005). Though syntactic priming occurs in production when there are no shared content words between the prime and the target utterance, there is an increase in the magnitude of the priming effect when there is a critical word present in both, such as a verb or noun (Pickering and Branigan 1998; Cleland and Pickering 2003). This increase in the priming effect in cases of lexical overlap has been termed the 'lexical boost'.

Syntactic Priming in Comprehension

All of the studies mentioned to this point have investigated priming for producing a particular target syntactic structure (due to either comprehending or producing a prime sentence with the same structure), but recent studies demonstrate that comprehending a sentence with a particular syntactic structure can ease the process of comprehending a subsequent sentence that has the same syntactic structure (Pickering and Traxler 2004; Arai et al. 2007; Ledoux et al. 2007; Weber and Indefrey 2009).[1] However, these observed syntactic priming effects in comprehension often appear to depend more on lexical repetition across prime and target sentences than those observed in production studies. For example, in one paradigm for investigating syntactic priming in comprehension, participants read difficult, garden-path sentences presented in prime–target pairs (such as 1 and 2, below) while having either their eye movements or electroencephalogram recorded.

1. Prime: The man *watched* by the woman was tall and handsome.
2. Target: The child *cleaned* by the girl was covered in chocolate.

Though these example sentences have the same syntactic structures, reading sentence 1 immediately before does not cause participants to read sentence 2 faster than normal (Pickering and Traxler 2004). However, if the prime and target sentences have equivalent structures, as well as the same initial verb, then target sentence reading time does decrease (as in 3 and 4, below). This priming effect has been shown for naturalistic reading using eye tracking (Pickering and Traxler 2004; Traxler and Tooley 2008), as well as physiologically via the P600 component of the event-related potentials (ERP) waveform to the disambiguating portion of reduced-relative sentences (during rapid serial visual presentation reading) (Ledoux et al. 2007; Tooley et al. 2009).

3. The man *watched* by the woman was tall and handsome.
4. The mouse *watched* by the cat was hiding under the table.

These findings may indicate that syntactic priming in comprehension is restricted to situations where the prime and target sentences share syntactic structure and a key lexical item (such as the initial verb) or that syntactic priming effects are only detectable in comprehension measures under these experimental conditions. Importantly, these results differ from those found in production, where significant priming effects are consistently present when only the syntactic structure, with no shared content words, is constant across the primes and targets.

Other recent investigations into syntactic priming in comprehension have tried to more closely match the task paradigms and stimuli used in production research, as these tasks/stimuli may simply be more sensitive to priming effects than those that require processing of difficult and infrequent sentence structures. Arai et al. (2007) used commonly occurring ditransitive sentences similar to those used in production studies, which could take either a DO or PO construction ('give the child the chocolate' vs. 'give the chocolate to the child'). Participants were shown a visual array of pictures of the subject, object, and recipient of each sentence, and fixations to these pictures were recorded. After reading a DO prime sentence, participants were more likely to fixate the recipient ('child') upon hearing the verb, whereas after reading a PO prime, they were more likely to fixate the object ('chocolate'). Yet again, this priming effect occurred only when the verbs in

the prime and target sentences were the same. However, there are some experimental findings that suggest that syntactic priming in comprehension does take place when there are different verbs across the primes and targets. Thothathiri and Snedecker (2008a,b) found significant priming effects when the verbs were different across prime and target sentences (see also Traxler 2008a for another example of lexically independent priming in comprehension). Thothatiri and Snedeker used a task similar to Arai et al. (2007), except that participants received two prime sentences, and they had to act out the target sentences with toy representatives of the recipients and objects. In light of this, it is possible that priming in comprehension takes place without verb repetition between primes and targets and that previous studies were just unable to detect these effects.[2]

Overall, the literature to this point implies that syntactic priming effects associated with comprehension of a target syntactic structure are readily detectable when both structural and lexical overlap (at the verb) are present between primes and targets. Yet, these effects have been less frequently observed in instances where only the syntactic structure is repeated across the prime and target sentences. This is in contrast to syntactic priming effects in production that are readily observed with no lexical overlap but are larger with lexical overlap between primes and targets. At the very least, priming effects in comprehension appear to be larger with lexical overlap than without, which is also the case for syntactic priming effects in production.

Discrepancies in Syntactic Priming Effects Across Modalities

PARADIGM/STIMULI DIFFERENCES ACCOUNT

Why are lexically independent syntactic priming effects detected more often in production than in comprehension? As previously noted, there are obvious paradigm and stimuli differences between the studies in these two areas of research. The dative (DO/PO) alternations that are most often used as stimuli in production experiments are more frequently occurring structures than the reduced-relative (garden-path) sentences used as stimuli in some comprehension research. Likewise, production paradigms often employ picture description tasks, whereas comprehension paradigms rely on online measures of processing difficulty, such as eye tracking or ERP, during reading (or listening). These inherent differences in stimuli, task paradigms, and dependent measures make it difficult to directly compare results in production to those in comprehension. This raises the possibility that the paradigms used in production tasks are more sensitive to syntactic priming effects than those used in comprehension tasks. If this is the case, then this could mean that both lexically independent and lexically dependent syntactic priming effects occur in comprehension but that the current task paradigms (save that of Thothathiri and Snedeker) are only sensitive enough to reveal the lexically dependent effects. Such an explanation has merit, given that syntactic priming effects in both modalities tend to have small effect sizes. These small effect sizes may make it extremely difficult to detect the lexically independent syntactic priming effects in online comprehension measures.[3]

A few published studies have used online measures to investigate syntactic priming effects in sentence production, and their findings lend some support to this account. Smith and Wheeldon (2001) measured voice-onset latencies of participants describing moving scenes. Target trials where two pictures moved in the same direction were primed with either a coordinated noun structure ('The eye and the fish move apart'. – primed condition) or a single noun structure ('The eye moves up and the fish moves down'. – unprimed condition). Participants were about 50 ms faster to begin speaking on

primed versus unprimed trials, and subsequent experiments ruled out non-structural explanations of this effect. Verb overlap was not manipulated in this set of studies (the verb was always 'move'), so these results only show that syntactic priming effects in production can be observed using online measures when the same verb is present across the prime and target sentences. Corley and Scheepers (2002) measured onset (typing) latencies for sentences produced in an online version of Pickering and Branigan (1998), Experiment 1. They found that participants initiated typing their completions faster when those responses had the same structure as the previous (prime) sentence than when they had a structure different from the prime sentence. However, this was based only on trials where there was also the same verb across primes and targets (because the lexically independent priming effects were not detected by an analysis using a categorical dependent variable of produced structure). These results do appear to be more similar to those found in many studies of syntactic priming in comprehension (Arai et al. 2007; Tooley et al. 2009) and suggest that syntactic priming effects may be more elusive in online measures in general, regardless of modality.

PROCESSING DIFFERENCES ACCOUNT

Production and comprehension are sometimes viewed as basically the same process that merely takes place in one order in one case and in the reverse order in the other. In production, the speaker has a message that they want to impart; they choose an appropriate syntactic structure for their message, select the words (or lexical items) they need, and then finally activate the phonological (or sound) information required to produce their sentence. In comprehension, the order of these events is reversed, but the basic processes remain the same. However, there are a number of subtle differences between comprehension and production because of the order in which different sub-processes take place (Bock 1990; see Levelt 1989; Levelt et al. 1999 for a lexicalist account). When planning an utterance, the speaker starts with an idea, which constrains their initial choice of possible syntactic structures that can be used to impart that idea (Bock 1990). On the other hand, when a listener or reader is trying to comprehend the meaning of a sentence, the individual words encountered and their order constrain the possible choices of syntactic structure. This is especially true for verbs, because they strongly constrain both syntactic and thematic processing. It is therefore not terribly surprising that syntactic priming effects in comprehension are strongly affected by verb repetition. Syntactic priming effects may manifest themselves somewhat differently in comprehension, compared to production, because of this inherent difference in the order of sub-processes and what that order entails for choice of syntax. Indeed, it has been shown that a prime sentence that is comprehended exerts just as much of an effect on the produced target sentence as a prime that was also produced (Bock et al. 2007). This implies that some change in the system does take place when a structure is comprehended (like when it is produced) and that this change influences the subsequent syntactic processes associated with producing a sentence. For the reasons noted above, this change may just be less obvious in subsequent comprehension processes. Though intuitively appealing, this explanation warrants experimental investigation before being accepted.

DIFFERENT MECHANISMS ACCOUNT

An alternative reason why lexically dependent syntactic priming effects in comprehension are more readily observable than lexically independent effects is that lexically independent

syntactic priming effects may be caused by different underlying mechanisms than lexically dependent syntactic priming effects. Some researchers have suggested that syntactic priming effects are caused by a short-term residual activation mechanism (Pickering and Branigan 1998; Pickering and Traxler 2004). Others view syntactic priming effects as a form of implicit learning of syntactic structure (Bock and Griffin 2000; Chang et al. 2006). Still, others have suggested that lexically dependent syntactic priming effects may be caused by a short-term mechanism, whereas lexically independent effects are caused by a more long-lived mechanism (Hartsuiker et al. 2008; Tooley 2009). Observable syntactic priming effects in comprehension are (for the most part) lexically dependent, meaning that they are most evident in cases when there is specific lexical (verb) overlap between the primes and targets (Arai et al. 2007). Both lexically independent and lexically dependent syntactic priming effects have been consistently observed in language production studies (Bock 1986; Pickering and Branigan 1998). If lexically independent and lexically dependent syntactic priming effects are caused by different underlying mechanisms, and only lexically dependent effects occur in comprehension (under an extreme interpretation of the literature), then this would imply that the mechanism that produces lexically independent syntactic priming effects in production does not manifest itself in comprehension processes. This logic rests on the premises that (i) lexically independent and lexically dependent syntactic priming effects are caused by different mechanisms and (ii) only lexically dependent syntactic priming effects take place in comprehension. Both of these premises are admittedly controversial, so this account should be considered cautiously. The different mechanistic accounts of syntactic priming effects, and how well they explain the patterns of results observed in comprehension and production, are reviewed in more detail in the following section and should shed light on this debate.

Mechanistic Accounts of Syntactic Priming Effects:

RESIDUAL ACTIVATION

Pickering and Branigan (1998) suggested that the mechanism responsible for the syntactic priming effects observed in language production is residual activation for a specific syntactic structure during production processes. They adopted Levelt's model of speech production (Levelt 1989) and Roelofs' specifications for the lemma stratum (Roelofs 1992, 1993) to help illuminate this mechanism. In this model, words are represented and activated at the conceptual level, activation then spreads to a lemma stratum, which represents linguistic category and possible syntactic structures (combinatorial nodes). Activation then finally spreads to the word-form stratum where phonological and morphological information is activated to produce the sounds involved in the speech output. When a certain syntactic structure has been recently produced (prime utterance), there is residual activation for that structure's combinatorial node. This activation is retained for a short time at that combinatorial node, and because it is linked to the other verbs that can take the structure specified by its combinatorial properties, this structure becomes more likely to be produced in subsequent utterances. This model specifies that there will also be residual activation for the link between recently produced lemmas (verbs) and the combinatorial node that was activated. This mechanism therefore predicts that there will be greater amounts of priming when a target utterance involves the same lemma (verb) as was produced in the prime utterance, because there is a summation of the residual activation present at the combinatorial node and that present at the link between the primed verb and the combinatorial node (see Pickering and Branigan 1998 for an illustration of

this mechanism). Findings of both lexically independent syntactic priming effects and the lexical boost effect in production provide support for this residual activation mechanism.

Pickering and Branigan's residual activation account stipulates that when a certain syntactic structure has been recently produced, there is residual activation for that structure's combinatorial node, which is shared with the other lemmas that can take that given structure. This model implies that lexically independent priming effects should occur because the shared combinatorial node retains activation (regardless of which verb is going to be produced in the target utterance). According to this model, lexically independent priming effects and the lexical boost are both caused by residual activation (more residual activation is present in the case of the lexical boost). Activation changes are conceived of as being rather transient, so this mechanism implies that syntactic priming effects should not persist across many (if any) intervening structures. However, Bock and Griffin (2000) found that lexically independent priming effects do persist across many (ten, for one structure tested) neutral filler sentences, implying that the mechanism causing these effects is more long-lived than would be predicted from transient activation changes. Hartsuiker et al. 2008 (see also Konopka and Bock 2005) also found that lexically independent syntactic priming effects persist across many intervening sentences but that the lexical boost does not persist across any intervening sentences. There is no obvious explanation in the Pickering and Branigan (1998) model for why residual activation for the combinatorial node should persist across many intervening sentences, nor why the time course of residual activation for the link between the lemma and the combinatorial node (which produces the lexical boost) should be so different from residual activation for the combinatorial node itself. In light of these findings, a residual activation mechanism as conceived by Pickering and Branigan (1998) cannot adequately account for the time course of syntactic priming effects in production.

IMPLICIT LEARNING ACCOUNT

Bock and Griffin (2000) and Chang et al. (2006) offer a different account of the mechanism producing syntactic priming effects in production. They suggest that the vast majority of the priming effects in production are likely due to long-term implicit learning effects, rather than short-term activation changes. Implicit learning is the unconscious acquisition of abstract information processing routines, over a period of time. When implemented as a computational model, repeated exposure to a particular sequence or structure changes the strengths of connections between the elements of that sequence or structure in a simulated neural network. Learning can only be considered implicit if it meets certain criteria: (i) learning is for an abstract rule or knowledge, not just information or an association; (ii) the rule or structure cannot be explicitly stated or verbalized by the learner; (iii) learning is not gained by explicit hypothesis testing but is coincidental to cognitive processing of information; and (iv) learning is preserved in amnesic patients (Seger 1994). Learning of grammatical structure satisfies all of these tenets (Ferreira et al. 2008) and so is a plausible candidate for the source of syntactic priming effects. However, classic studies of implicit grammar learning (e.g. Reber 1967, 1969; Gordon and Holyoak 1983) have used nonsense letter strings as stimuli and were based on artificially created grammatical structures. As such, little is known about how this type of learning could affect a language system that is already highly sophisticated and stocked with acquired grammatical knowledge.

Bock and Griffin (2000) claim that the mechanism that produces priming for syntax is 'enhanced strength in the connections between representational units that support the

use of syntactic structure'. In support of this claim, these authors showed that syntactic priming effects persisted for one particular structure, even when there were up to ten intervening structures between the primes and targets. Such long-lived effects are not indicative of short-term activation changes, which would degrade more quickly. These authors claim that the enhanced priming effects that have been observed in instances of lexical overlap (the 'lexical boost') are not evidence for residual activation of the structure that is bound to the repeated lexical item but rather reflect explicit memory for the wording of the prime. The repeated lexical item becomes a cue when a sentence is being planned and so biases the speaker to repeat the structure that was recently used.

Other researchers have also found long-lived priming effects, which support an implicit learning account of syntactic priming in production. Gries (2005) used linear regression models to investigate the existence of syntactic priming in real-world circumstances using examples of naturalistic speech taken from the ICE-GB (English language, Great Britain) corpora. These analyses suggested that syntactic priming in naturalistic speech is very robust, and persists across multiple intervening utterances. Chang et al. (2006) modeled the implicit learning account in a model based on a connectionist recurrent network with a dual-route architecture and error-based learning. These simulations produced similar priming effects to those found experimentally, including the finding that changes in syntactic preference are more permanent and long-lived than would be predicted by residual activation accounts. However, the lexical boost effect was not observed using this simulation, which renders this mechanism unable to account for the full range of syntactic priming effects. There is also evidence that supports the implicit learning explanation for lexically independent syntactic priming effects in comprehension. Luka and Barsalou (2005)[4] conducted a series of experiments in which participants read sets of sentences, completed a 5- minute distracter task, and then rated sentences (some from the original set, others novel) for grammatical acceptability. Participants rated sentences as more grammatical when they had previously read those exact sentences, as well as when they had read sentences with the same syntactic structure. Important to the current discussion, the grammaticality judgments took place after a long time lag, and many intervening sentences. These results remained constant when only one instance of a grammatical structure appeared in the training set and suggest exposure affects grammatical knowledge. Wells et al. (2009) had participants in one group read many difficult object-relative sentences over four sessions and then compared self-paced reading times of both subject and object relatives to individuals in a control condition. Before the four sessions of training, both groups had longer reading times on the object-relative sentences, which are generally considered to be more difficult than subject relatives. After the four training sessions, participants in the control condition still showed this pattern of reading times, but participants that had been exposed to the object relatives during the four sessions showed no difference in reading times between the subject and object relatives. Thus, exposure to the object-relative structure decreased the online processing difficulty of this structure. Results from this diverse set of studies point to a mechanism that causes long-term facilitation of syntactic structure, possibly implicit learning.

DUAL MECHANISM ACCOUNT

A further kind of hypothesis, the *dual mechanism account*, may provide explanations for the pattern of priming effects in comprehension and production. According to the dual mechanism account, lexically independent syntactic priming effects are caused by an implicit learning mechanism, whereas lexically dependent priming effects are caused by a

more short-term mechanism, such as residual activation. Like Bock and Griffin (2000), Hartsuiker et al. (2008) manipulated the number of intervening sentences in a set of both spoken and written production tasks. Syntactic priming effects in both modalities persisted for up to six intervening sentences; however, the increase in the magnitude of the priming effects associated with having the same verb across the primes and targets (the lexical boost) did not persist across any number of intervening structures. These results suggest that while lexically independent priming effects appear to be long-lived in production, the additional priming effect from the lexical repetition (lexically dependent priming effects) is not. The different durations that have been observed for lexically dependent and independent syntactic priming effects suggest that these effects may be driven by at least two underlying mechanisms. The dual mechanism model that we propose attributes lexically independent syntactic priming effects to an implicit learning mechanism, whereas lexically dependent priming effects would be explained by a more short-lived mechanism (possibly residual activation). The residual activation mechanism that we propose is one that is very similar to Pickering and Branigan's but that specifies only residual activation for the link between a specific verb and the combinatorial node of the previously encountered structure, and not for the combinatorial node itself (see Figure 1, below). Such a mechanism would predict verb-specific priming effects, such as those observed in the many comprehension studies. Furthermore, this dual mechanism model of syntactic priming effects would predict that lexically dependent effects would be short lived (as residual activation is) but that lexically independent effects would be long-lived.

This dual mechanism account implies that the lexically dependent syntactic priming effects in comprehension, which constitute the majority of the observed syntactic priming effects in comprehension, are caused by residual activation, rather than implicit learning. Before this account can be accepted, it is essential to investigate the time course of syntactic priming effects in comprehension. Recent research suggests that (lexically dependent) syntactic priming effects in comprehension persist across 2 intervening sentences (Carminati and van Gompel 2009). If lexically dependent syntactic priming effects are

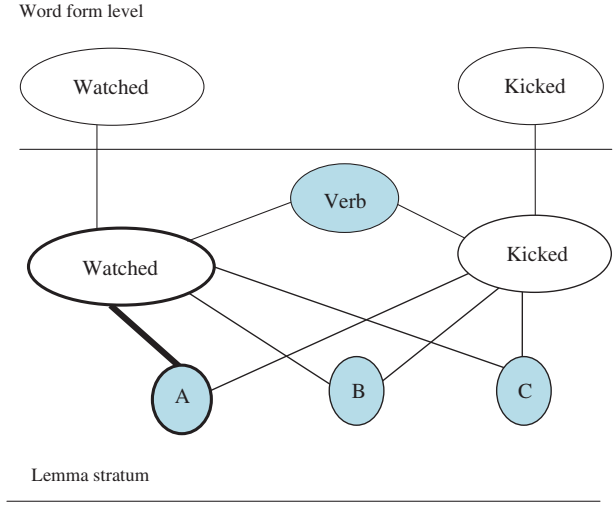

Fig 1. Modified residual activation mechanism (based on residual activation mechanism proposed by Pickering and Branigan 1998): Residual activation is restricted to the link between the verb that appeared in a particular structure and the combinatorial node that represents that structure (structure A, in this figure).

shown to be long-lived in comprehension (unlike the lexical boost in production), then this could suggest that either residual activation is not the mechanism producing these effects or residual activation for comprehension-to-comprehension information is more long-lived than for production-to-production information (or comprehension-to-production). Additional research that establishes the exact longevity of these effects in comprehension is critical to understanding the mechanism that produces lexically dependent syntactic priming effects in both modalities.

Future Research Directions

Research into syntactic priming of comprehension processes is still quite recent. As such, there are still many questions to address and much research that needs to be done in this area. Ideally, future research will provide a direct comparison of syntactic priming effects in comprehension and production, using the same paradigm and stimuli (and ideally involving the same participants within a single experiment). This is sorely needed to adequately address whether there truly exists a discrepancy in the level of lexical dependency across syntactic priming in comprehension and production. Additional research should also be done to test for structural priming in syntactic structures other than those typically used in this type of research. Finally, serious efforts should be directed at explicitly testing the different mechanistic accounts of syntactic priming effects. To do this, more investigations into the time courses of lexically dependent and lexically independent priming effects should be undertaken. Answering these and other pertinent questions will hopefully build a parsimonious model of syntactic priming and lead to an improved understanding of how syntax is represented and processed in both production and comprehension.

Concluding Remarks

Our review has shown that syntactic priming effects are observed in both production and comprehension. While lexically independent priming effects appear more often in studies of production than in studies of comprehension, lexically independent priming has been observed in some studies of comprehension. Thus, similar mechanisms and processes may account for syntactic priming outcomes in both comprehension and production, including the finding that priming effects are larger in both modalities when verbs (and possibly other word types) appear in both the prime sentence and the target sentence. To account for this *lexical boost* and for longer-lived priming effects in both comprehension and production, we advanced the dual mechanism hypothesis, under which both lexically driven access to syntactic structure information and implicit learning processes account for different components of the observed priming effects. However, considerable work remains to be done to delineate the limits of lexically driven priming effects in comprehension, in terms of both how long such effects persist and the range of syntactic structures in which they occur. Finally, more direct comparisons between comprehension and production involving the same sentence types and the same individuals would also help clarify the extent to which mechanisms and processes common to both modalities contribute to syntactic priming effects.

Short Biography

Kristen Tooley received her PhD in Psychology from the University of California, Davis, in 2009. She is currently a postdoctoral researcher at the University of Illinois,

Urbana-Champaign, affiliated with the Psychology Department and the Beckman Institute. Her main research interests focus on syntactic representation and processing using syntactic priming paradigms. More recently, she has also begun researching syntactic representation within the realms of language production and language acquisition.

Acknowledgement

This project was supported by awards from the National Science Foundation (0446618) and by the National Institutes of Health (1R01HD048914-01A2), both awarded to MT.

Notes

* Correspondence: Kristen Tooley, Department of Psychology, University of Illinois, Urbana-Champaign, 2123 Beckman Institute, 405 N. Matthews Ave. Urbana, IL 61801, USA. E-mail: ktooley@illinois.edu

[1] We categorize syntactic priming effects in production as being those where the target sentence is being produced (regardless of whether the prime sentence was produced or comprehended); syntactic priming effects in comprehension are only those cases where comprehension processes associated with the target sentence structure are facilitated.
[2] However, this result could possibly reflect a task-specific effect due to the fact that participants were given two prime sentences rather than one and had to not only comprehend the target sentences, but also had to plan and execute actions, which could have invoked covert production of the sentences.
[3] Arguing against this possibility are the plethora of subtle language-processing effects detected by eye tracking and ERP across a wide range of stimulus and task conditions (see, e.g. Rayner, 1998; Kutas et al., 2006).
[4] Note, however, that this study fails to rule out an account under which 'syntactic acceptability' ratings really reflect a general familiarity effect, rather than a change in the strength of specific kinds of syntactic representations.

Works Cited

Arai, M., R. P. G. van Gompel, and C. Scheepers. 2007. Priming ditransitive structures in comprehension. Cognitive Psychology 54(3). 218–50.
Bock, J. K. 1986. Syntactic persistence in language production. Cognitive Psychology 18. 355–87.
——. 1990. Structure in language: creating form in talk. American Psychologist 45. 1221–36.
——, G. S. Dell, F. Chang, and K. H. Onishi. 2007. Persistent structural priming from language comprehension to language production. Cognition 104. 437–58.
Bock, K., and Z. M. Griffin. 2000. The persistence of structural priming: transient activation or implicit learning? Journal of Experimental Psychology: General 129(2). 177–92.
——, and H. Loebell. 1990. Framing sentences. Cognition 35. 1–39.
Branigan, H. P., M. J. Pickering, and A. A. Cleland. 2000a. Syntactic co-ordination in dialogue. Cognition 75. B13–25.
——, ——, A. J. Stewart, and J. F. McLean. 2000b. Syntactic priming in spoken production: linguistic and temporal interference. Memory & Cognition 28. 1297–302.
Carminati, M. N., and R. P. van Gompel. 2009. Time course of structural priming in comprehension. Paper presented at the 22nd annual CUNY conference on human sentence processing, Davis, CA. March 26–28, 2009.
Chang, F., G. S. Dell, and K. Bock. 2006. Becoming syntactic. Psychological Review 113(2). 234–72.
Cleland, A. A., and M. J. Pickering. 2003. The use of lexical and syntactic information in language production: evidence from the priming of noun phrase structure. Journal of Memory and Language 49. 214–30.
——, and ——. 2006. Do writing and speaking employ the same syntactic representations? Journal of Memory and Language 54. 185–98.
Corley, M., and C. Scheepers. 2002. Syntactic priming in English sentence production: categorical and latency evidence from an internet-based study. Psychonomic Bulletin & Review 9. 126–31.
Ferreira, V. S., J. K. Bock, M. P. Wilson, and N. J. Cohen. 2008. Memory for syntax despite amnesia. Psychological Science 19. 940–6.
Gordon, P. C., and K. J. Holyoak. 1983. Implicit learning and generalization of the "mere exposure" effect. Journal of Personality and Social Psychology 45. 492–500.
Gries, S. T. 2005. Syntactic priming: a corpus-based approach. Journal of Psycholinguistic Research 34(4). 365–99.

Hartsuiker, R. J., S. Bernolet, S. Schoonbaert, S. Speybroeck, and D. Vanderelst. 2008. Syntactic priming persists while the lexical boost decays: evidence from written and spoken dialogue. Journal of Memory and Language 58. 214–38.

——, and H. H. J. Kolk. 1998b. Syntactic persistence in Dutch. Language and Speech 41. 143–84.

——, M. J. Pickering, and E. Veltkamp. 2004. Is syntax separate or shared between languages? Cross-linguistic syntactic priming in Spanish-english bilinguals. Psychological Science 15(6). 409–14.

Huttenlocher, J., M. Vasilyeva, and P. Shimpi. 2004. Syntactic priming in young children. Journal of Memory and Language 50. 182–5.

Konopka, A. E., and J. K. Bock. 2005. Helping syntax out: what do words do? Paper presented at the CUNY Sentence Processing Conference, Tucson, Arizona.

Kutas, M., C. Van Petten, and R. Kluendez. 2006. Psycholinguistics electrified II: 1994–2005. Handbook of psycholinguistics, ed. by M. Traxler and M. A. Gernsbacher, 2nd Edition, 659–724, New York: Elsevier.

Ledoux, K., M. Traxler, and T. Y. Swaab. 2007. Syntactic priming in comprehension: evidence from event-related potentials. Psychological Science 18(2). 135–43.

Levelt, W. J. M. 1989. Speaking: from intention to articulation. Cambridge, MA: MIT Press.

——, A. Roelofs, and A. S. Meyer. 1999. A theory of lexical access in speech production. Behavioral and Brain Sciences 22. 1–75.

Levelt, W. J. M., and S. Kelter. 1982. Surface form and memory in question answering. Cognitive Psychology 14(1). 78–106.

Loebell, H., and K. Bock. 2003. Structural priming across languages. Linguistics 41. 791–824.

Luka, B. J., and L. W. Barsalou. 2005. Structural facilitation: mere exposure effects for grammatical acceptability as evidence for syntactic priming in comprehension. Journal of Memory and Language 52. 436–59.

Meijer, P. J. A., and J. E. Fox Tree. 2003. Building syntactic structures in speaking: a bilingual exploration. Experimental Psychology 50. 184–95.

Neely, J. H. 1977. Semantic priming and retrieval from lexical memory: roles of inhibitionless spreading activation and limited-capacity attention. Journal of Experimental Psychology: General 106. 226–54.

Pickering, M. J., and H. P. Branigan. 1998. The representation of verbs: evidence from syntactic priming in language production. Journal of Memory and Language 39. 633–51.

——, and M. J. Traxler. 2004. Syntactic priming in comprehension. Paper presented to the CUNY Sentence Processing Conference. College Park, MD.

Rayner, K. 1998. Eye movements in reading and information processing: 20 years of research. Psychological Bulletin 85. 618–60.

Reber, A. S. 1967. Implicit learning of artificial grammars. Journal of Verbal Learning and Verbal Behavior 6. 855–63.

——. 1969. Transfer of syntactic structure in synthetic languages. Journal of Experimental Psychology 81. 115–9.

Roelofs, A. 1992. A spreading-activation theory of lemma retrieval in speaking. Cognition 42. 107–42.

——. 1993. Testing a non-decompositional theory of lemma retrieval in speaking: retrieval of verbs. Cognition 47. 59–87.

Savage, C., E. Lieven, A. Theakston, and M. Tomasello. 2003. Testing the abstractness of children's linguistic representations lexical and structural priming of syntactic constructions in young children. Developmental Science 6(5). 557–67.

Scheepers, C. 2003. Syntactic priming of relative clause attachments: persistence of structural configuration in sentence production. Cognition 89. 179–205.

Seger, C. A. 1994. Implicit learning. Psychological Bulletin 115(2). 163–96.

Shin, J. A., and K. Christianson. 2009. Syntactic processing in Korean-English bilingual production: evidence from cross-linguistic structural priming. Cognition 112(1). 175–80.

Smith, M., and L. Wheeldon. 2001. Syntactic priming in spoken sentence production- an online study. Cognition 78. 123–64.

Thothathiri, M., and J. Snedecker. 2008a. Give and take: syntactic priming during spoken language comprehension. Cognition 108. 51–68.

——, and ——. 2008b. Syntactic priming during language comprehension in three and four year old children. Journal of Memory & Language 58. 188–213.

Tooley, K. M. 2009. Is syntactic priming in sentence comprehension really just implicit learning? Paper presented to the 22nd Annual CUNY Conference on Human Sentence Processing, Davis, March 26–28.

——, M. J. Traxler, and T. Y. Swaab. 2009. Electrophysiological and behavioral evidence of syntactic priming in sentence comprehension. Journal of Experimental Psychology: Learning, Memory, and Cognition 35(1). 19–45.

Traxler, M. J. 2008a. Lexically independent syntactic priming of adjunct relations in on-line sentence comprehension. Psychonomic Bulletin and Review.

——, and K. M. Tooley. 2008. Priming in sentence comprehension: strategic or syntactic? Language and Cognitive Processes.

Weber, K., and P. Indefrey. 2009. Syntactic priming in German-English bilinguals during sentence comprehension. NeuroImage 46. 1164–72.
Wells, J. B., M. H. Christiansen, D. S. Race, D. J. Acheson, and M. C. MacDonald. 2009. Experience and sentence processing: statistical learning and relative clause comprehension. Cognitive Psychology 58. 250–71.

Further Reading

Bernolet, S., R.J. Hartsuiker, and M.J. Pickering. 2007. Shared syntactic representations in bilinguals: evidence for the role of word-order repetition. Journal of Experimental Psychology: Learning, Memory, & Cognition 5. 931–49.
Boland, J.E., and H. Boehm-Jernigan. 1998. Lexical constraints and prepositional phrase attachment. Journal of Memory and Language 39(4). 684–719.
Branigan, H.P., M.J., Pickering, S.P., Liversedge, and A.J., Stewart. 1995. Syntactic priming: investigating the mental representation of language. Journal of Psycholinguistic Research 24. 489–506.
Branigan, H.P., M.J., Pickering, and A.A., Cleland. 1999. Syntactic priming in written production: evidence for rapid decay. Psychonomic Bulletin & Review 6. 635–40.
Branigan, H.P., M.J., Pickering, and J.F., McLean. 2005. Priming prepositional phrase attachment during comprehension. Journal of Experimental Psychology: Learning, Memory, & Cognition 31. 468–81.
Carminati, M.N., R.P.G., van Gompel, C., Scheepers, and M., Arai. 2008. Syntactic priming in comprehension: the role of argument order and animacy. Journal of Experimental Psychology: Learning, Memory, and Cognition 5. 1098–110.
Chang, F., G. S., Dell, K., Bock, and Z. M., Griffin. 2000. Structural priming as implicit learning: a comparison of models of sentence production. Journal of Psycholinguistic Research 29. 217–29.
Ferreira, F., and C., Jr. 1986. The independence of syntactic processing. Journal of Memory and Language 25. 348–68.
Ferreira, F., and K. K., McClure.1997. Parsing of garden-path sentences with reciprocal verbs. Language and Cognitive Processes 12 (2&3). 273–306.
Friederici, A. D., A., Hahne, and A., Mecklinger. 1996. Temporal structure of syntactic parsing: early and late event-related brain potential effects. Journal of Experimental Psychology: Learning, Memory, & Cognition 22(5). 1219–48.
Long, D. L., and C. S., Prat. 2008. Individual differences in syntactic ambiguity resolution: readers vary in their use of plausibility information. Memory & Cognition 36(2). 375–91.
MacDonald, M. C., N. J., Pearlmutter, and M. S., Seidenberg. 1994. Lexical nature of syntactic ambiguity resolution. Psychological Review 101. 676–703.
Melinger, A., and C., Dobel. 2005. Lexically-driven syntactic priming. Cognition 98. B11–20.
Osterhout, L., and P.J., Holcomb. 1992. Event-related brain potentials elicited by syntactic anomaly. Journal of Memory and Language 31(6). 785–806.
Osterhout, L., P.J., Holcomb, and D.A., Swinney. 1994. Brain potentials elicited by garden-path sentences: evidence of the application of verb information during parsing. Journal of Experimental Psychology: Learning, Memory, & Cognition 20. 786–803.
Pickering, M.J., H.P., Branigan, A.A., Cleland, and A.J., Stewart. 2000. Activation of syntactic information during language production. Journal of Psycholinguistic Research 29(2). 205–16.
Pickering, M.J., and R.P.G., van Gompel. 2006. Syntactic Parsing. The handbook of psycholinguistics, 2nd Edition, ed. by M.J. Traxler and M.A. Gernsbacher, 455–504. London, England: Elsevier.
Scheepers, C., and M.W., Crocker. 2004. Constituent order priming from reading to listening: a visual-world study. The on-line study of sentence comprehension, ed. by M. Carreiras and C. Clifton, Jr. 167–185. New York, NY: Psychology Press.
Shin, J.A. 2008. Structural priming in bilingual language processing and second language learning. Dissertation presented to the Department of Educational Psychology at the University of Illinois, Urbana-Champaign.
Traxler, M.J., R.S., Williams, S.A., Blozis, and R.K., Morris. 2005. Working memory, animacy, and verb class in the processing of relative clauses. Journal of Memory and Language 53. 204–24.
Traxler, M.J. 2008b. Structural priming among prepositional phrases: evidence from eye-movements. Memory & Cognition.
Traxler, M.J., and M.J., Pickering. 2005. The Lexical Basis of Syntactic Priming in Comprehension. Paper presented to the CUNY Sentence Processing Conference. Tucson, AZ.
Trueswell, J.C., and A.E., Kim. 1998. How to prune a garden path by nipping it in the bud: fast priming of verb argument structure. Journal of Memory and Language 39. 102–10.