UC San Diego
UC San Diego Previously Published Works

Title
Thirty years of structural priming: An introduction to the special issue

Permalink
https://escholarship.org/uc/item/0pg4680c

Authors
Dell, Gary S
Ferreira, Victor S

Publication Date
2016-12-01

DOI
10.1016/j.jml.2016.05.005

Peer reviewed

Thirty years of structural priming: Introduction to the special issue

Gary S. Dell

University of Illinois, Urbana-Champaign

Victor S. Ferreira

University of California, San Diego

Gary S. Dell

Beckman Institute

University of Illinois

Urbana, Illinois, 61801

217-244-1294

gdell@illinois.edu

The 1980s was a time of great change in psycholinguistics. Connectionism was stirring and the *Journal of Verbal Learning and Verbal Behavior* had just become the *Journal of Memory and Language*. An important driving force in the field was the emergence of new linguistic frameworks, frameworks that changed the way we think about the relations between syntax and semantics and between syntax and the lexicon (e.g. Lexical Functional Grammar, Bresnan, 1982). At the same time, researchers were starting to take production seriously and include it in experimental psycholinguistics. Not coincidentally, a smalltown *Projektgruppe* was transformed into the Max Planck Institute for Psycholinguistics.

Against this backdrop, the experimental study of syntactic processes in production was inevitable. The most influential of such studies were those that demonstrated the persistence of syntactic structures, also known as structural or syntactic priming. *Lexical* persistence, the tendency for words and turns of phrases to recur in conversations had been established (e.g. Kubovy, 1977; Schenkein, 1980). The power of lexical persistence had been demonstrated in a remarkable experiment using just the telephone. Levelt and Kelter (1982) found that telephoned merchants, when asked, "**At** what time do you close?" would say something like "**At** five" around 60% of the time. The answers included the preposition only 40% of the time, though, when the question was "What time do you close?"

What also seemed to be true was that abstract patterns repeat. We admire authors who use parallel constructions to illustrate commonalities or contrasts, whether the prose is purple ("It was the best of times, it was the worst of times,") or blue ("Shaken, not stirred."). Levelt and Kelter's study can be interpreted as demonstrating lexical or structural repetition, or both, and Schenkein (1980) provided examples from real conversations that, like the famous opening to *A Tale of Two Cities*, repeat both the words and the structures that the words inhabit.

This special issue on structural priming appears 30 years after Bock (1986), the first controlled study of the priming of purely structural abstractions during production. In that paper, the primed abstractions were very much like surface syntactic structures—hierarchical phrase markers whose terminals are grammatical categories rather than lexical items. Structural choices involving active versus passive and prepositional versus double-object dative alternations were influenced by the structure of the immediately previous sentence, even when that previous sentence was lexically and semantically unrelated, and this priming was neither diminished nor enhanced by conceptual factors. The method seemed to truly isolate syntactic aspects of sentence production. Although Garrett's (1975) analysis of speech errors showed that production engages syntactic processes, the discovery of structural priming reified those processes and made them more amenable to experimental investigation. So powerful were the implications of Bock's findings that one of us recalls a famous psychologist saying that he/she did not believe the results, because if they were true, the field would be forced to accept the isolability of syntactic operations, which would presumably have clashed with the psychologist's strongly held beliefs.

Today, disbelief in structural priming is not an option. Mahowald et al.'s (2016, this issue) meta-analysis shows why. Structural priming in production has been found many times and the priming main effects, at least those in experiments, are not small. Furthermore, there is now no doubt that Bock's contention that the priming effect can be independent of variations in meaning is true. The latest demonstration of this fact is provided here by Huang et al. (2016), whose experiments found semantically independent structural priming in Mandarin Chinese, a language which has few morphological cues to syntactic structure.

An important discovery about structural priming is the "lexical boost," the tendency for priming effects to be greater when the prime and target sentences share content words (typically, the verb; Pickering & Branigan, 1998). Mahowald et al.'s meta-analysis tells us that the lexical boost is the most powerful "moderator" of priming, but also that its influence quickly disappears when sentences intervene between prime and target. The meta-analysis also tells us that the lexical boost has been one of the most studied priming moderators. Why so much interest? Recall that a central feature of structural priming is that it occurs when there is no lexical overlap between prime and target sentences (including function words, e.g. Bock, 1989). If no-overlap priming, however, is small in comparison to that obtained when the verb is repeated, it inclines one toward a theory of production in which structure building is tightly interwoven with the retrieval of lexical items. Before we draw this conclusion, though, we must discover how the boost works. Several of the papers in this special issue provide relevant data (e.g. Branigan & McLean; Feher et al.; Fricke & Kootstra; Huang et al., Segaert et al.).

Bock's (1986) paper reflected the then current debates about syntax. What was less appreciated about the paper, though, was that it echoed another major movement in 1980s cognitive psychology, the contrast between explicit and implicit memory. When one says, "a church is struck by lightning" after experiencing a prime sentence like "the referee was punched by one of the fans," one is implicitly remembering the syntactic structure of the prime episode.

Thus, in Bock (1986) we see claims both about the isolability of syntactic processes in production and about the implicit use of prior linguistic experience when speaking. Subsequent research on structural priming—initially done largely by Bock and her colleagues--built on both of these claims, but did so at different times. The history of priming is a tale of two cities. During the decade following the 1986 paper, the research continued its focus on the separateness of syntax from semantics and from the lexicon (e.g. Bock & Loebell, 1990). Let us associate this research with Cambridge, Massachusetts. Early in her career, Bock spent time at MIT, famously the home of generative grammar, modularity, and the "east pole" of cognitive science. At the millennium, another city, Champaign, Illinois, enters the picture, and priming research turned to questions of learning and memory. Bock and Griffin (2000), both at the University of Illinois, demonstrated that priming can be long lasting and proposed that it is a form of implicit learning. Although the Cambridge-style questions are still investigated in priming experiments, today it is the midwest that rules the roost. Most prominently, the learning-based accounts suggested by Bock and Griffin have evolved into current adaptationist and rational accounts (e.g., Jaeger & Snider, 2013) that are part of the broader movement toward such accounts across the cognitive sciences.

Research on structural priming has since traveled west and then gone trans-Atlantic. In California, Herb Clark has long been foregrounding research on language in naturalistic, communicative contexts, culminating in his 1996 book *Using Language*. Cognitive psychologists have often viewed natural communication as experimentally intractable, which arguably has stunted the growth of the investigation of the mechanisms underlying such communication using cognitive frameworks. Structural priming proved to be a powerful tool to overcome such challenges. In particular, the first demonstration that structural priming arises between interacting live interlocutors (Branigan et al., 2000) led to a highly influential theoretical framework (Pickering & Garrod, 2004), at the heart of which is the phenomenon of structural priming and its most prominent moderating factor, the lexical boost. This led to extensive investigation throughout the aughts and teens on the relationship between the structure of language, processes of memory and attention, and the factors that operate in naturalistic communication (a compelling example of which can be found in Branigan et al, 2007).

Which brings us to the present. Here are some of the key unresolved questions that are addressed in the special issue:

How long lasting is the priming? Bock and Griffin (2000) found priming undiminished after 10 sentences, and others have discovered that the influence of multiple primes accumulates and that such cumulative effects can last at least a week (Kaschak et al., 2011). The current papers replicate long-lag priming when prime and target are lexically unrelated and demonstrate that priming effects accumulate (e.g. Segaert et al., Cho-Reyes et al., Branigan & McLean, Bernolet et al.). Furthermore, as noted before, the lexical boost effect quickly decays (Branigan & McLean). These facts are well established. But what does it all mean?

Implicit and explicit memory. To explain the temporal properties of priming, we need a theory of how primes are remembered and how they are forgotten. If priming comes from an implicit echo of prime processing, it should be registered in long-term memory as a part of the procedures involved in speaking. But what about the explicit memory for the prime? Ferreira et al. (2008) found that amnesic speakers, who lack the ability to form (or retrieve) explicit episodic memories of sentences, have intact long-lasting structural priming. In this issue, Bernolet et al. (2016) directly compare explicit memory for sentence structure and structural priming as a function of lag. One of their results was expected: Explicit memory for structure is very quickly lost. Their other result was not expected: Purely structural priming is considerably stronger when the target immediately follows the prime. If structural priming is somehow increased by explicit memory for structure, the unexpected result can be explained. An increase in structural priming from explicit memory has in fact been proposed for why the lexical boost to priming is largely restricted to trials when the prime and target are adjacent (e.g. Chang et al., 2006).

Learning mechanisms for priming = learning mechanisms for language acquisition? Structural priming is a product of how the mind learns and remembers linguistic material. So is language acquisition. Thus, it was natural to ask whether priming relates to acquisition. The claim that structural priming is just the continuation of language acquisition is a central feature of many accounts of priming, whether they are realized in a probabilistic (Bayesian) model (e.g. Jaeger & Snider, 2013; Fine & Jaeger, 2013), a general cognitive architecture such as ACT-R (Reitter, et al. 2011) or a recurrent connectionist

network (e.g. Chang et al., 2006; MacDonald & Christiansen, 2002). An important feature of all of these models is that the long-term effect of a prime should be greater when the prime structure is less common—the inverse frequency effect. This effect is the natural outcome of a mechanism that learns most when its current expectations are violated. The inverse frequency effect has been supported experimentally (e.g. Bernolet & Hartsuiker, 2010) and in corpora (e.g., Jaeger & Snider, 2013). Here, it receives additional support from Segaert et al.'s (2016) study, which reports that production choices are strongly influenced by passive-voice (less-frequent) primes, but not by active primes. Surprisingly, though, priming as measured by response time to begin speaking works oppositely. It is active, rather than passive, primes that speed up the production of sentences with the primed structure. Segaert et al.'s decision model is able to account for both the RT and choice data, by proposing both long- and short-term aspects of priming (as in Reitter et al., 2011 and Pickering & Branigan, 1998). Cho-Reyes et al.'s (2016) study of structural priming in speakers with aphasia adds a new wrinkle to the inverse preference effect: The more severe the deficit, the greater the priming. This is the result expected from the perspective that aphasia impairs the basis for structural expectations, without impairing the ability to rebuild that basis.

But what about actual language acquisition? Three papers in the special issue are relevant. Branigan and McLean (2016) report that the long-lasting structural priming and the transient lexical boost observed in adult speakers also apply to three and four year olds in an experimental dialogue setting. Their study provided the first demonstration that children this age show the lexical boost effect (see, Rowland et al., 2012). Feher et al. (2016) examine priming that arises in a newly learned artificial grammar. When the grammar is learned in a communicative setting, priming can be viewed as part of the mechanism for reducing variation—or increasing alignment--among interlocutors. Fraundorf and Jaeger (2016) demonstrate the structural priming of a dialect-specific form, namely, the "needs" construction that is spoken by speakers in particular regions including western Pennsylvania (e.g., "the article needs written"). What's more, they show that when speakers unfamiliar with this form learn it, they generalize it to a new unattested form (e.g., "the copier will recycled because…").

Other kinds of priming? "Structural" priming implies priming of a syntactic structure, but if other kinds of structures are relevant, there is no reason why they should not prime as well. Chang, Bock, and Goldberg (2003) and, now, Cho-Reyes et al., (2016) demonstrated a sensitivity to the patterning of thematic roles, independently of syntactic structure. A noteworthy extension of structural priming is provided by Fricke and Kootstra (2016), who examine priming in English-Spanish codeswitched utterances. They raise the possibility that the pattern of language mixing is a structural feature subject to priming. Bott and Chemla (2016) demonstrate a genuinely new form of priming, namely, the priming of pragmatic enrichment. For example, if participants are compelled to interpret "some" not as its more conventional "some but not all," but instead as the logical, "some and in fact all," not only are they more likely to subsequently interpret another "some" in a similar (logical) way, but will interpret other statements similarly (e.g., "there are four diamonds" to mean, "there are at least four diamonds").

We conclude by summing up the legacy of 30 years of research on structural priming. In his textbook, Harley (2014) claims that there are four central issues in the psychology of language:

innateness, modularity, rules versus associations, and the relation between language and other mental functions. Structural priming research hits the psycholinguistic quadfectra, as priming studies provide data addressing all four of Harley's issues. Moreover, the pervasive influence of the priming data in psycholinguistics forces theoretical treatments of priming to take an exceptionally broad view. Priming models (e.g. Chang et al., 2006; Dell & Chang, 2014; Jaeger & Snider, 2013; Pickering & Branigan, 1998; Reitter et al., 2011) must make claims about linguistic representations and psychological processes, and link these with principles of learning, memory, and development. In this respect, the models are channeling the catholic spirit of Bock (1986).

What is perhaps most remarkable about structural priming is that, unlike many other discoveries in the cognitive sciences, it escaped the curse of merely being a "phenomenon," and instead became something that, even if understated, is much more useful: A measure. A powerful, reliable measure that permits insights into the enigma that is syntax – abstract structure. In becoming a measure, structural priming has told us more about the inner workings of the mind than just the fact that syntax repeats, and therefore that it exists. Syntax exists, it is learned and adapts, it reflects communicative forces, it is separate from but tightly interrelated to representations of events, meaning, words, and sounds, and it is subject to the forces of memory and attention.

This special issue is dedicated to our colleague, mentor, and friend, Kathryn Bock.

References

Bernolet, S., & Hartsuiker, R. J. (2010). Does verb bias modulate syntactic priming? *Cognition*, *114*, 455-461.

Bock, J.K. (1986). Syntactic persistence in language production. *Cognitive Psychology* 18, 355-387.

Bock, K. (1989). Closed-class immanence in sentence production. *Cognition* 31, 163-186.

Bock, K. & Loebell, H. (1990). Framing sentences. *Cognition* 35, 1-39.

Bock, K. & Griffin, Z.M. (2000). The persistence of structural priming: Transient activation or implicit learning? *Journal of Experimental Psychology: General* 129, 177-192.

Branigan, H.P., Pickering, M.J., & Cleland, A.A. (2000). Syntactic coordination in dialogue. *Cognition* 75, B13-B25.

Branigan, H.P., Pickering, M.J. McLean, J.F., & Cleland, A.A. (2007). Syntactic alignment and participant role in dialogue. *Cognition* 104, 163-197.

Bresnan, J. (1982). *The mental representation of grammatical relations*. Cambridge, MA: MIT Press.

Chang, F., Bock, K. & Goldberg, A.E. (2003). Can thematic roles leave traces of their places? *Cognition* 90, 29-49.

Chang, F., Dell, G.S., & Bock, K. (2006). Becoming syntactic. *Psychological Review* 113, 234-272.

Clark, H.H. (1996). *Using language*. Cambridge, U.K.: Cambridge University Press.

Dell, G.S., & Chang, F. (2014). The P-Chain: Relating sentence production and its disorders to comprehension and acquisition. *Philosophical Transactions of the Royal Society B*, 369, 20120394.

Ferreira, V.S., Bock, K., Wilson, M.P., & Cohen, N.J. (2008). Memory for syntax despite amnesia. *Psychological Science* 19, 940-946.

Fine, A.B. & Jaeger, T.F. (2013). Evidence for implicit learning in syntactic comprehension. *Cognitive Science* 37, 578–591.

Garrett, M.F. (1975). The analysis of sentence production. In G.H. Bower (Ed.), *The psychology of learning and motivation*, Vol. 9 (pp. 133-175). London: Academic Press.

Harley, T.A. (2014). *The psychology of language: From data to theory* (fourth edition). London: Psychology Press.

Jaeger, T.F. & Snider, N.E. (2013). Alignment as a consequence of expectation adaptation: Syntactic priming is affected by the prime's prediction error given both prior and recent experience. *Cognition* 127, 57-83.

Kaschak, M.P., Kutta, T.J., & Schatschneider, C. (2011). Long-term cumulative structural priming persists for (at least) one week. *Memory & Cognition* 39, 381-388.

Kubovy, M. (1977). Response availability and the apparent spontaneity of numerical choices. *Journal of Experimental Psychology: Human Perception and Performance* 3, 359-364.

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

MacDonald, M.C. & Christiansen, M.H. (2002). Reassessing working memory: Comment on Just and Carpenter (1992) and Waters and Caplan (1996). *Psychological Review* 109, 35-5.

Pickering, M.J., & Branigan, H.P. (1998). The representation of verbs: Evidence from syntactic priming in language production. *Journal of Memory and Language* 39, 633-651.

Pickering, M.J. & Garrod, S. (2004). Toward a mechanistic psychology of dialogue. *Behavioral and Brain Sciences* 27, 169-190.

Reitter, D., Keller, F., & Moore, J.D. (2011). A computational cognitive model of syntactic priming. *Cognitive Science* 35, 587-63.

Rowland, C.F., Chang, F., Ambridge, B., Pine, J.M., & Lieven, E.V.M (2012). The development of abstract syntax: Evidence from structural priming and the lexical boost. *Cognition* 125, 49-63.

Schenkein, J. (1980). A taxonomy of repeating action sequences in natural conversation. In B. Butterworth (Ed.), *Language production*, vol. 1 (pp. 21–47). London: Academic Press.