Automatic Analogical Reasoning Underlies Structural Priming in Comprehension of Ambiguous Sentences

Vencislav Popov (vencislav.popov@gmail.com)
Penka Hristova (phristova@cogs.nbu.bg)
Department of Cognitive Science and Psychology,
New Bulgarian University, 21 Montevideo Street
Sofia 1618, Bulgaria

Abstract

The structure of previous sentences influences both production and comprehension of subsequent sentences, although there is less support for the latter. This effect, called structural priming, supposedly results from the repetition of syntactic structure, while evidence for the influence of thematic roles is controversial. We suggest that structural priming is achieved by automatic analogical mapping and transfer, which predicts that the thematic structure should be primed too. An experiment showed that the shared thematic structure is responsible for structural priming in comprehension of ambiguous sentences, rather than the syntactic structure. When participants read an unambiguous base sentence with an instrumental thematic role, they tended to interpret the corresponding role in the ambiguous prepositional phrase in the target as an instrument as well. This effect was present only when base and target sentences shared their whole thematic structure, not only the key role and in the absence of syntactic repetition.

Keywords: structural priming, automatic analogy, thematic roles, ambiguous sentences, language comprehension

Introduction

Here we present an experiment with ambiguity. Now, the truth is that our study is *about* ambiguity, but can you really determine this from the previous sentence without doubt? No, it can also be easily interpreted to mean that our presentation will be ambiguous, and although no article would begin with such a confession, both interpretations are equally grammatical if not equally probable. Traditional theories of sentence comprehension propose that structural ambiguity is resolved by purely syntactic considerations (Frazier & Fodor, 1978; Pickering & Ferreira, 2008). But can syntactic parsing be affected by semantic factors as well?

Sentences such as the one we began with contain a structural ambiguity called prepositional phrase attachment (PPA) ambiguity (Schütze & Gibson, 1999). In such sentences, a prepositional phrase (PP) can be attached either to the verb or to the immediately preceding noun. For example, in the sentence "The hunter watched the alpinist with binoculars." the PP can modify either the verb *watched* or the noun *the alpinist*. Whereas the hunter is watching the alpinist *through* binoculars in the verb-attachment condition, in the noun-attachment condition, the alpinist *had* the binoculars. This difference can be conceptualized in terms of thematic roles too. When the PP modifies the verb, it serves as an instrument of the action, and when the noun is modified, it serves as its attribute.

Traditionally, the preferential parsing of one or the other alternative has been explained by the minimal attachment principle and by the late-closure strategy (Frazier & Fodor, 1978). According to the minimal attachment principle, the parser tries to construct the simplest possible syntactic structure, which happens when the PP is verb-attached. On the other hand, the late-closure strategy proposes that new lexical items are attached to the current constituent to reduce working memory load. In that case, the PP would be attached to the immediately preceding noun phrase.

Recent research indicates that some extraneous factors can influence syntactic parsing as well. Branigan, Pickering, and McLean (2005) used the structural priming paradigm to show that the choice of analysis can be primed by a structurally similar sentence. They argued that it was the repetition of syntax across sentences which influenced interpretation. However, both the thematic[1] and the syntactic structures were shared in their stimuli, and it is not clear which was responsible for the effect. In fact, priming of thematic structure was shown by Goldwater, Tomlinson, Echols, & Love (2011), who suggested that analogical mapping and transfer underlie structural priming in production. We had two goals – to disentangle the effects of syntactic and thematic structure in comprehension-to-comprehension structural priming and to test the suggestion that analogical reasoning is responsible for the effects. First we turn to a discussion of relevant findings.

Structural priming

Structural priming[2], the tendency for structural repetition across utterances, has been extensively used for studying processes both during sentence production (Bock, 1986; Bock & Loebell, 1990; Pickering & Branigan, 1998; Goldwater et al, 2011) and during comprehension (Branigan et al., 2005; Thothathiri & Snedeker, 2008; Boudewyn, Zirnstein, Swaab, & Traxler, 2013). Initial studies of structural priming in production showed that the effects cannot be explained by semantic or thematic factors (Bock, Loebell, & Morey, 1992; Bock & Loebell, 1990). Because of that, syntactic repetition has been used as an argument in favor of an abstract syntax (Bock & Loebell, 1990; Pickering & Ferreira, 2008).

[1] The organization of thematic roles in a sentences

[2] By "structural priming" we denote the effects of all structural repetitions. We will use the modifiers "syntactic" and "thematic" when we discuss priming of the specific structures.

While structural priming is a robust phenomenon in sentence production, it can be elusive in comprehension (Pickering & Ferreira, 2008, Thothathiri & Snedeker, 2008). Evidence for it there comes mainly from eye-tracking data, where participants seem to predict which object would be mentioned next, if the current sentence follows the structure of the previous one (Arai, Van Gompel, & Scheepers, 2007; Thothathiri & Snedeker; 2008). Branigan et al. (2005) presented behavioral evidence by using an expression-to-picture matching task, in which participants read prime and target sentences with PPA ambiguity. After reading each sentence, participants view two pictures and had to choose the one which matched the content of the previous sentence. One of the pictures after the prime matched either the verb- or the noun-attachment of the PP, whereas the other matched neither, which disambiguated the prime. In contrast, the two pictures after the target matched both of its possible interpretations. Participants chose the verb-attachment picture for the target more often when the PP in the base was also verb-attached, and vice-versa.

Their results, however, are not necessarily due to syntactic priming, but may also reflect the priming of thematic structure. Their prime and target expressions shared both structures – in the verb-attachment condition, the PP was interpreted as an instrument of the action, whereas in the noun-attachment condition, it was an attribute of the object in the noun-phrase. While acknowledging that fact, the authors argued that semantic similarity is somewhat minimized in their stimuli, and that priming in comprehension is probably like priming in production, where some studies show that thematic roles do not contribute to it (Bock, Loebell, & Morey, 1992; Bock & Loebell, 1990). However, they never tested this possibility and it represents a serious confound.

In fact, there is ample evidence that thematic relations *do* play a significant role in structural priming in production and that they can be assigned independently of the syntactic structure (Pickering & Ferreira, 2008). For example, contrary to the expectations of syntactic priming, DO dative sentences can prime preposition-object (PO) dative constructions, given that they share their thematic structure (Hare and Goldberg, 1999). Similarly, when syntactic structure is kept constant, the order of the thematic roles can be independently primed (Chang et al., 2003). While these effects were shown in production, not comprehension, they make the alternative explanation of Branigan et al's (2005) results more plausible.

Analogical reasoning

Not only is the alternative theoretically plausible, but it can be predicted by a model rooted in analogical reasoning (Taylor, Friedman, Forbus, Goldwater, & Gentner, 2011). The model is based on Gentner's (1983) structure-mapping theory – it acquires abstract language patterns from experience by generalization, and constructs new sentences by analogy to structurally similar sentences. It demonstrates structural priming in production by retrieving recently activated patterns in working memory, and it does it with fewer learning trials, compared to other computational models in the field (Chang, Dell, & Bock, 2006).

Because analogical reasoning is reasoning about entities not based on their attributes, but rather based on the roles they fill in a certain relational structure (Holyoak, 2012), this approach to structure priming predicts an increase in production not only of the same syntactic structure, but of the thematic structure as well. This prediction was confirmed by Goldwater et al's. (2011) who showed that when 4 and 5 year old children are primed with a PO dative phrase, they not only produce more PO datives than DO datives, but also produce both constructions more often than other non-dative constructions. Furthermore, 4 year old children show thematic structure priming only when the surface similarity between the prime and target expressions is high, but they show no syntactic priming. Yet, 5 year olds show both types of priming in both high and low similarity conditions. This is precisely the case for analogy and is uniquely predicted by this account.

To elaborate further, most structural priming studies usually present participants with a prime expression, in which both syntactic and semantic information contribute to its relational structure, and then people either have to produce or comprehend another structurally similar sentence. A person faced with that task can retrieve an analogous sentence from memory, then map the roles in the structure of the analog to the corresponding roles in the target, and finally generate inferences for the upcoming information based on the mapping of those roles (Gentner & Smith, 2012).

Consider the expression-to-matching task that Branigan et al. (2005) used. After the base was disambiguated, people had an active representation of it in memory with the following thematic structure: agent – patient – instrument. Afterwards they saw a novel expression in which the first two roles were again agent and patient, while the third one was ambiguous. If the person maps the first two roles they can then generate an inference about what the ambiguous role should be. This predicts that the effect should be present even when the syntactic structure between sentences is different.

While this suggestion seems reasonable, an objection can be raised. Researchers often assume that structural priming is automatic[3], but analogical reasoning is argued to be a complex, intentional and computationally expensive cognitive process (Spellman, Holyoak, & Morrison, 2001; Cho, Holyoak, & Cannon, 2007; Holyoak & Hummel, 2008). According to some studies (Holyoak, 2012), people cannot spontaneously find and use analogies to solve complex problems, and they cannot even benefit from relational similarities in simple structures such as subsequent word pairs in a lexical decision task (Spellman et al., 2001). Indeed, it is hardly believable that a conscious intentional process could underlie an automatic one. Yet, evidence is accumulating that analogical mapping and transfer can sometimes happen both unintentionally and without awareness (Blanchette & Dunbar, 2002; Day & Gentner, 2005; Hristova, 2009; Day & Golstone, 2011; Perrott & Gentner, 2005). However, Holyoak

[3] unintentional, unconscious, efficient and/or uncontrollable (Bargh, 1994)

(2012) notes that the unintended transfer in some studies may be merely the result of priming of the key relational concept and that it is not due to systematic mapping of the entire relational structure. None of the aforementioned studies included a condition in which only the key concept is shared, but not the whole relational structure, so Holyoak's (2012) objection is still relevant. In the experiment presented below, we address this problem by adding such a condition for control.

In summary, modelling structural priming as analogical reasoning predicts that the interpretation of ambiguous sentences will be influenced by a preceding sentence which shares their thematic structure even in the absence of syntactic similarities. This prediction was confirmed for sentence production in children (Goldwater et al, 2011), but has not been tested in adults or with comprehension. We undertook the following experiment to test that prediction, and to disentangle the effects of syntactic and thematic priming for structural priming in comprehension.

Experiment

We used an adapted version of the task used by Branigan et al. (2005) to test it. The target was a sentence with a PPA ambiguity (1):

(1) The hunter watched the alpinist with binoculars
(2) The doctor watched the patient by using glasses
(3) The doctor watched the patient who wore glasses
(4) The doctor and the patient watched by using glasses
(5) The doctor and the patient, who wore glasses, watched
(6) The doctor watched the patient and smiled.

The base was an unambiguous sentence which differed syntactically from the target, and its key role was either an instrument of the action (2, 4) or an attribute of the preceding noun-phrase (3, 5). To address Holyoak's (2012) concern about the automaticity of analogies, the base was also varied on whether it shared its whole thematic structure with the target (2, 3) or only its key role (4, 5). A final control base (6) was added with which to estimate priming relative to a null condition. If people comprehend the ambiguity by using analogy, they will tend to interpret the PP as an instrument more often when the corresponding role in the base is also an instrument, and if this is due to analogical reasoning and not priming of the key relational concept, the effect will be present only when the structures are analogous.

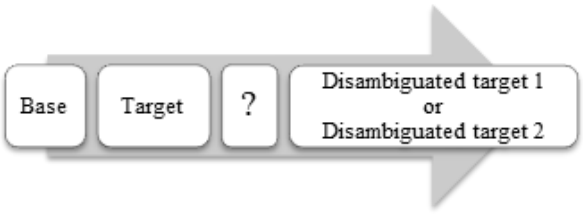

Figure 1. Time course of a single trial; each panel represents successive screens.

Methods

Participants

Forty undergraduates at New Bulgarian University participated for partial fulfillment of course credit (25 women). All were native Bulgarian speakers at mean age 24.58 years (*SD* = 7.08), ranging from 18 to 51 years.

Procedure

Each sentence was presented individually on a computer screen with E-prime 2.0 software. A single experimental trial consisted of an unambiguous base sentence followed by an ambiguous target sentence and a comprehension test for the target (fig. 1). Experimental trials were mixed with filter trials and participants were not aware of any connection between the sentences. They also thought that comprehension test would appear randomly. The instructions were to read the sentences carefully because sometimes they will have to choose which one of two sentences expresses the same meaning as the preceding sentence. Reading was self-paced and participants pressed a button to proceed to the next sentence. A red question mark appeared 500 ms after each target, and after half of the fillers, but after none of the bases. It was followed by a comprehension test, which consisted of two alternative sentences, presented one under the other. For target items, those were the two disambiguated version of the target as presented in table 1, whereas for fillers one expressed the same meaning, the other a slightly different one. Their position (i.e. top vs bottom) was counterbalanced across participants. Participants pressed a button on a SRBOX to choose the sentence that matched the way they understood the immediately preceding sentence. The experiment began with ten practice trials of additional fillers, some of which were ambiguous.

At the end participants answered two questions: 1) "Did you notice any connection between consecutive sentences?", 2) "Do you think that your interpretation of some sentences might have been influenced by the preceding sentence?"

Materials

There were 20 sets of experimental stimuli; each consisted of one ambiguous target sentence, five different base sentences, and two disambiguated versions of the target that matched each of its possible interpretations. A single set is presented in table 1. All target sentences had the same thematic structure, *agent – patient – ambiguous (instrument or attribute)*, and all of them could be interpreted with both verb- and noun-attachment of the ambiguous PP.

None of the content words were used in more than one set and the base and target sentences shared only their verb. All non-control versions of each base used the same verb and arguments. Half of the base sentences ended with the adverbial clause "by using X" (instrumental), the other half ended with the relative clause "who wore X" or "who had X" (attributive). Within each role condition, one of the sentences was analogical to the target, and had the same thematic structure, *agent – patient – instrument/attribute*, whereas the

Table 1. A complete set of translated items for a single target sentence (the original stimuli were in Bulgarian).

Item	Type of role	Type of structure	Sentence
Target	-	-	The hunter watched the alpinist with binoculars.
Disambiguated target 1	Instrumental	-	The alpinist was watched by binoculars.
Disambiguated target 2	Attributive	-	The alpinist with the binoculars was watched.
Base 1	Instrumental	Analogical	The doctor watched the patient by using glasses.
Base 2	Instrumental	Non-analogical	The doctor and the patient watched by using glasses.
Base 3	Attributive	Analogical	The doctor watched the patient who wore glasses.
Base 4	Attributive	Non-analogical	The doctor and the patient, who wore glasses, watched.
Control base	-	-	The doctor watched the patient and smiled.

other one was not analogical to the target, and had the structure agent – agent – instrument/attribute.

40 unambiguous filler sentences of various grammatical structures intervened between experimental trials, and none of them shared content words with the experimental sentences. There were additional "catch trials", which mirrored the structure of the base sentences. Because they were not followed by ambiguous targets, this made it unlikely that participants will consciously generate expectancies for the targets (Boudewyn, Zirnstein, Swaab, & Traxler, 2013). Another ten sentences had a relative clause ambiguity, such as "The mistress searched for the phone of the man that she lost." to draw some attention away from the targets.

Experimental items were placed into five lists with four targets per each type of base in each list. Each participant saw only one of the base sentences per target, and base sentences were counter-balanced between-subject across lists, so that each target was presented with each base equally often. This controlled for possible confounds of the specific pairings of words, phrases, etc. The 100 experimental and filler items were randomized for each participant with the constraint that each target followed immediately after its respective base, and at least two fillers appeared after each target.

Design

We used a 2 (type of role: instrumental base vs attributive base) by 2 (type of structure: analogical base vs non-analogical base) within-subject design and all variables were manipulated over base sentences. The control base was used only to estimate the relative size of the priming in a subsequent analysis and was not part of the design. Each participant saw four targets in each condition and chose either an instrumental or an attributive interpretation of each target, which was the main dependent variable. Reading times for the target we also recorded.

Results

The traditional ANOVA has known problems for analyzing aggregated percentages data, so we analyzed the raw results with mixed-effects logistic regressions with random effects for subjects and items (Baayen, Davidson, & Bates, 2008). Both analyses lead to the same conclusions, so only the latter is presented. The basic model included subjects and items as intercept random effects. Including random slopes for subject and items did not improve the model fit, $\Delta AIC = 25.13$, LLR $\chi^2(10) = 4.86$, $p = .89$, therefore we assume that the priming effect is invariant across subjects and items, and we continue with the initial model. First, we tested the effect of type of role. Adding it to the model as a fixed effect significantly increased its fit, $\Delta AIC = -15.09$, LLR $\chi^2(1) = 17.085$, $p < .001$ – people were more likely to interpret the target instrumentally, when the key role in the base was instrumental as well ($M = .62$, $SE = .028$), than when it was attributive ($M = .48$, $SE = .028$). There was no effect of type of structure, $\Delta AIC = -2$, LLR - $\chi^2(1) = 0.003$, $p = .96$ ($M = .55$, $SE = .028$ for the analogical base, $M = .553$, $SE = .028$ for the nonanalogical base). The interaction however improved the model significantly, $\Delta AIC = -4.26$, LLR $\chi^2(1) = 6.26$, $p < 0.05$. To explore the interaction we split the data in half by type of structure, and analyzed the type of role effect for the two datasets. Instrumental interpretations of the target increased significantly after an instrumental base only when the base was analogical to the target ($\Delta M = 22.5\%$), $\Delta AIC = -19.21$, LLR $\chi^2(1) = 21.208$, $p < 0.001$, but not when the base was not analogical ($\Delta M = 5.6\%$), $\Delta AIC = 0.63$, LLR $\chi^2(1) = 1.37$, $p = .243$.

Next we compared the performance in each experimental condition to the control condition to estimate the direction of the priming. The factors of type of role and type of structure were collapsed with the control condition to form a single fixed effect with five levels. Including this factor significantly improved the basic model, $\Delta AIC = -18.16$, LLR $\chi^2(4) = 26.165$, $p < .001$. All conditions were compared to the control condition, which was the reference category. Only the instrumental analogical condition differed significantly from the control, *odds ratio* = 2.6, $SE = 1.31$, $z = 3.515$, $p < .001$ (table 2).

Due to the self-paced reading procedure, reading times (RTs) were extremely dispersed (overall $M = 3857$ ms., $SD = 2148$ ms, range from 421 ms. to 17661 ms.). We tried several different procedures to deal with outliers, including different cut-off values, both absolute and SD based, log and inverse transformations (Ratcliff, 1993). Because they produced very different results, we could not choose one without bias and without increasing the method's degrees of freedom.

Table 2. Mean proportion of instrumental interpretation of the target by base type; logistic regression parameters

Type of base	M (SE)	Odds (95CI)*	Wald z
Instrumental, analogical	0.66 (0.04)	2.6 (1.53, 4.43)	3.51 **
Attributive, analogical	0.44 (0.04)	0.7 (0.42, 1.17)	-1.35
Instrumental, nonanalogical	0.58 (0.04)	1.58 (0.94, 2.66)	1.72
Attributive, nonanalogical	0.53 (0.04)	1.14 (0.68, 1.92)	0.50
Control	0.50 (0.04)		

Note: * the control base was the reference category; ** $p < .001$

None of the participants noticed the structural similarity of consecutive sentences and no one reported their interpretation of some sentences to have been influenced by the immediately preceding sentence.

Discussion

We demonstrated that a shared thematic structure is sufficient to elicit structural priming in comprehension even in the absence of syntactic repetition. In a target sentences, such as "The hunter watched the alpinist *with binoculars"*, participants interpreted the ambiguous role as an instrument of the action more often when the corresponding role in the base was also an instrument (The doctor watched the patient *by using glasses*), compared to when it was an attribute of the preceding noun-phrase (The doctor watched the *patient who wore glasses*). The effect was present only when the whole structure of the base was analogous to the target – the nonanalogical base "*The doctor and the patient watched by using glasses"* did not increase the amount of instrumental interpretations of the target, although its key role was instrumental. Therefore the effect was not due to the activation and priming of the key concept *instrument*, as Holyoak (2012) has previously suggested, but the result of systematic mapping.

Moreover, people were neither instructed that there was a connection between sentences, nor did they notice the repetition of thematic structure between expressions. Thus, the analogies were performed both unintentionally and unconsciously. Although other studies reported evidence for automatic analogies (Blanchette & Dunbar, 2002; Day & Gentner, 2005; Day & Golstone, 2011; Perrott & Gentner, 2005), this is the first study that directly addresses Holyoak's (2012) concern. While behavioral criteria here point to automatic processing (Bargh, 1994), reaction times were harder to interpret. Lack of stability and statistical significance prevents us from making a conclusion about the online processing of comprehension. Furthermore, if a difference was found, it is not clear how we would have interpreted the data. Branigan et al. (2005) analyzed reaction times only when the target interpretation was forced by the procedure, which allowed them to make conclusions about the ease of processing or transfer. Subsequent studies should be designed to allow interpretation of reading times, and they should control reading times much better than ours, for example, by using the moving-window procedure.

Overall, we confirmed the predictions of Goldwater et al. (2011) and Taylor et al. (2011), who suggested that analogical structure-mapping underlies structural priming. While their computational model and empirical results were concerned with production, and were tested only in children, we extended this work to comprehension and adults. Specifically, adults seem to interpret structurally ambiguous sentences partially by analogy when primed with structurally similar expressions.

Our results complement the limited work on structural priming in comprehension by providing direct evidence for the role of thematic structure. The effect size we obtained of 22.5% is comparable with Branigan et al.'s (2005) effect of 18% in comprehension-to-comprehension and the 21% effect in production-to-comprehension. Since the syntactic and thematic structures were both repeated in their stimuli and ours only shared their thematic structure we conclude that the effect is likely due to the shared thematic structure. One limitation of this conclusion is that the studies used different stimuli sets, although similar in structure, and for some reason the effect might be simply stronger with ours - syntactic structure might have an incremental effect, however small. Further work should directly compare the two structures for a more clear conclusion.

The idea that structural priming is achieved by analogy also explains the semantic boost effect – verb repetition across prime and targets enhances structural priming and is sometimes even required for the effect to appear, because superficial similarity aids the retrieval of analogues (Holyoak, 2012). This boost is largely unexplained by the syntactic approach (Pickering & Ferreira, 2008). We are currently testing (similarly to Goldwater et al., 2011) whether structural priming would appear even if the verb is not same, but it is semantically similar, i.e. expresses a similar action (*to direct* vs *to orient*).

Finally, based on our results and the accumulating literature on the differential influence of thematic roles and syntax (Hare & Goldberg, 1999; Chang et al., 2003), we suggest that it will probably be useful to make a conceptual and terminological distinction between syntactic, thematic and structural priming (a related suggestion was put forward by Goldwater et al., 2011, as well). Full structural priming should probably denote only the more general effects of repeated structure and it could be divided into the subordinate concepts of syntactic and thematic structure priming. With this conceptual distinction in hand interesting questions can be derived for which we do not have a clear answer – what are the relative contributions of each to structural priming in general? Are their effects additive or do they interact in a meaningful way?

Conclusions

Semantic factors, such as the thematic roles that objects play in a sentence, can influence syntactic parsing – structural priming is successfully achieved in comprehension when the thematic structure is shared even in the absence of syntactic repetition. Most likely this is done by automatic analogical mapping and transfer – faced with ambiguity people retrieve expressions with a similar relational structure, map the unambiguous roles and make inferences for the ambiguous ones based on that mapping. Analogical reasoning seems to be a crucial element of language comprehension.

Acknowledgments

We are grateful to Georgi Petkov with whom we had fruitful discussions. We thank Radoslav Nedyalkov and Elena Mikova, who gathered the data.

References

Arai, M., Van Gompel, R. P., & Scheepers, C. (2007). Priming ditransitive structures in comprehension. *Cognitive Psychology*, 54(3), 218–250.

Bargh, J. (1994). The four horsemen of automaticity: Intention, awareness, efficiency, and control as separate issues. *Handbook of Social Cognition*, *1*, 1–40.

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language*, *59*(4), 390–412.

Blanchette, I., & Dunbar, K. (2002). Representational change and analogy: How analogical inferences alter target representations. *JEP: LMC*, 28, 672-685.

Bock, J. K. (1986). Syntactic persistence in language production. *Cognitive Psychology*, *18*(3), 355–387.

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

Bock, K., Loebell, H., & Morey, R. (1992). From conceptual roles to structural relations: bridging the syntactic cleft. *Psychological Review*, *99*(1), 150.

Boudewyn, M. A., Zirnstein, M., Swaab, T. Y., & Traxler, M. J. (2013). Priming prepositional phrase attachment: Evidence from eye-tracking and event-related potentials. *The Quarterly Journal of Experimental Psychology*, 1–31.

Branigan, H. P., Pickering, M. J., & McLean, J. F. (2005). Priming Prepositional-Phrase Attachment During Comprehension. *JEP: LMC*, *31*(3), 468–481.

Chang, F., Bock, K., & Goldberg, A. E. (2003). Can thematic roles leave traces of their places? *Cognition*, *90*(1), 29–49

Chang, F., Dell, G. S., & Bock, K. (2006). Becoming syntactic. *Psychological Review*, *113*(2), 234.

Cho, S., Holyoak, K. J., and Cannon, T.D. (2007). Analogical reasoning in working memory: Resources shared among relational integration, interference resolution, and maintenance. *Memory & Cognition*, 35 (6), 1445-1455

Day, S. & Gentner, D. (2007). Nonintentional analogical inference in text comprehension. *Memory and Cognition*, 35, 39-49.

Day, S., & Goldstone, R. (2011). Analogical transfer from a simulated physical system. *JEP: LMC*, 37, 551-567.

Frazier, L., & Fodor, J. D. (1978). The sausage machine: A new two-stage parsing model. *Cognition*, 6, 291–325.

Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. *Cognitive Science*, *7*(2), 155–170.

Gentner, D., & Smith, L. (2012). Analogical reasoning. *Encyclopedia of Human Behavior (2nd Ed.), VS Ramachandran, Ed. Elsevier*

Goldwater, M., Tomlinson, M., Echols, C., & Love, B. (2011). Structural Priming as Structure-Mapping: Children Use Analogies From Previous Utterances to Guide Sentence Production. *Cognitive Science*, *35*(1), 156–170

Griffin, Z. M., & Weinstein-Tull, J. (2003). Conceptual structure modulates structural priming in the production of complex sentences. *Journal of Memory and Language*, *49*(4), 537–555.

Hare, M. L., & Goldberg, A. E. (1999). Structural priming: Purely syntactic? In *Proceedings of the 21st annual meeting of the Cognitive Science Society* (pp. 208–211).

Holyoak, K. J. (2012). Analogy and relational reasoning. *The Oxford Handbook of Thinking and Reasoning*

Holyoak, K. J., & Hummel, J. E. (2008). No way to start a space program: Associationism as a launch pad for analogical reasoning. *Behavioral and Brain Sciences*, *31*(04), 388–389.

Hristova, P. (2009). Unintentional and Unconscious Analogies Between Superficially Dissimilar but Relationally Similar Simple Structures In B. Kokinov, K. Holyoak & D. Getner (Eds.), *New Frontiers in Analogy Research*,193-203.

Perrott, D., Gentner, D., & Bodenhausen, G. (2005). Resistance is futile: The unwitting insertion of analogical inferences in memory. *Psychonomic Bulletin & Review*, 12, 696-702.

Pickering, M. J., & Branigan, H. P. (1998). The Representation of Verbs: Evidence from Syntactic Priming in Language Production. *Journal of Memory and Language*, *39*(4), 633–651.

Pickering, M. J., & Ferreira, V. S. (2008). Structural priming: A critical review. Psychological Bulletin, 134(3), 427–459

Ratcliff, R. (1993). Methods for dealing with reaction time outliers. *Psychological Bulletin*, *114*(3), 510–532.

Schütze, C. T., & Gibson, E. (1999). Argumenthood and English prepositional phrase attachment. *Journal of Memory and Language*, *40*(3), 409–431.

Spellman, B. A., Holyoak, K. J., & Morrison, R. G. (2001). Analogical priming via semantic relations. *Memory & Cognition*, *29*(3), 383–393

Taylor, J., Friedman, S., Forbus, K., Goldwater, M., & Gentner, D. (2011). Modeling structural priming in sentence production via analogical processes. In *Proceedings of the 33rd Annual Conference of the Cognitive Science Society*, 2916-2921

Thothathiri, M., & Snedeker, J. (2008). Give and take: Syntactic priming during spoken language comprehension. *Cognition*, *108*(1), 51-68