Is Structural Priming in Children Facilitated by Interactions between Animacy and Syntax?

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Abstract

Sentence production relies on the activation of both semantic information (e.g. noun animacy) and syntactic frames that specify an order for grammatical functions (e.g. subject before object; Levelt, Roelofs & Meyers, 1999). However, it is unclear whether these semantic and syntactic processes interact (Gámez & Vasilyeva, 2015), and if this changes developmentally. We thus examined the extent to which animacy-semantic role mappings in dative prime sentences and target scenes influenced choice of syntactic structure. 143 participants (47 three year olds, 48 five year olds and 48 adults) alternated with the experimenter in describing animations. Animacy mappings for themes and goals were either prototypical or non-prototypical and either matched or mismatched across the experimenter's prime scenes and participants' target elicitation scenes. Prime sentences were either double-object datives (e.g. *the girl brought the monkey a ball)* or prepositional datives (e.g. *the girl brought the ball to the monkey*). Participants' target sentences were coded for syntactic form. All age groups showed a main structural priming effect. For the youngest group, animacy-semantic role mappings facilitated prepositional dative priming. No animacy facilitation was found for the older groups. Our results demonstrate the changing influence of animacy cues on sentence production through interactions with syntactic structure over the course of development. The theoretical implications of our findings are discussed.

Keywords: structural priming; animacy; language production; semantics; syntax.

Introduction

In order to communicate ideas, speakers must map concepts to syntactic structures. Where one idea can be expressed using multiple structures, speakers tend to use the most recently heard structure (Bock, 1986). For example, structural priming occurs where speakers are more likely to describe the transfer of a ball between a girl and a monkey using the double-object dative (DOD) sentence *the girl brought the monkey a ball* instead of the prepositional dative (PD) structure *the girl brought a ball to the monkey,* following a DOD, rather than a PD prime. This occurs in children (Rowland, Chang, Ambridge, Pine & Lieven, 2012) and adults (Bock, 1986).

In their residual activation theory, Pickering and Branigan (1998) argue that abstract representations of verbs, grammatical roles (e.g. direct object) and combinatorial notes are activated upon hearing a DOD sentence (i.e. NP-NP). Structural priming occurs where speakers reuse the currently activated NP-NP node to produce another DOD construction rather than activating the alternative NP-prepositional phrase (PP) node to produce a PD sentence.

The residual activation theory cannot, however, account for instances where structural priming is enhanced by animacy-syntax interactions. Gámez and Vasilyeva (2015) found that priming of passive sentences in children was greatest where primes and targets both contained animate patients and inanimate agents. For datives, animacy may interact with semantic role-grammatical function mappings (e.g. theme-direct object), before these mapped constituents are ordered, to determine syntactic structures (de Swart, Lamers & Lestrade, 2008). Prototypical DOD sentences contain animate goals before animate themes, whereas prototypical PD sentences feature inanimate themes before animate goals (Bresnan, Cueni, Nikitina & Baayen, 2007). Demuth, Machobane, Maloi and Odato (2005) found that children best understood double object applicatives in Sesotho where they contained human, rather than inanimate, benefactives before inanimate, as opposed to animate, themes. These studies suggest that structural and semantic information may be inseparable and represented at varying levels of granularity (Ambridge, Kidd, Rowland & Theakston, 2015).

However, methodological problems with structural priming studies have made it unclear whether animacy-syntax interactions could drive priming effects (Chang, Bock & Goldberg, 2003). DOD sentences (e.g. *the girl brought the monkey a ball*) may prime participants to repeat the abstract syntactic frame and produce DOD targets. Alternatively, they may prime speakers to reuse the *animate-inanimate* noun ordering, leading them to produce PD sentences where targets contain animate themes and inanimate goals (e.g. *the boy brought the tiger to the zoo*). Studies manipulating both prime and target animacy cues are needed to identify whether semantic processes influence structural priming (Goldwater, Tomlinson, Echols & Love (2010).

Priming could be greater with semantically prototypical primes (e.g. Vasilyeva & Waterfall, 2015). Alternatively, priming might be greater with non-prototypical primes because they are more salient, according to Chang, Dell and Bock's (2006) error-based learning theory. Error-based learning effects may decrease with age due to increased exposure to uncommon sentence types (Peter, Chang, Pine, Blything & Rowland (2015). Priming is greater in children (Goldwater, et al., 2010) and adults (Cleland and Pickering, 2003) where primes and targets are semantically similar. Sensitivity to animacy and its effects on structural priming may also decrease with age (Corrigan, 1988).

Priming research may provide insight into how children extract representations of grammatical functions and animacy-semantic role mappings from caregiver speech to produce their own sentences (Bock, Dell, Chang & Onishi, 2007; Pickering & Ferreira, 2008). By investigating possible specification of semantic, and not just lexical, information in children's sentence representations, we can more accurately conclude whether or not representations are entirely abstract (Rowland & Noble, 2010).

We assessed the extent to which structural priming in three year olds, five year olds and adults was influenced by interactions between animacy cues and syntax by manipulating prime structures (DOD/PD), prime animacy-semantic role mappings (prototypical [AN goal & IN theme]/non-prototypical [AN theme & IN theme]), and prime-target match in animacy-semantic role mappings (match/mismatch).

Prior research implies relatively strong interactions between animacy and syntax and that these effects on sentence processing are greater in younger children than in older children and adults. Thus, we tested the following hypotheses: (i) structural priming effects will be greater where primes have prototypical animacy cues. Alternatively, error-based learning may entail greater priming with reversed cues, (ii) priming will be greater where primes and targets have matching animacy-semantic role mappings, (iii) the relative increase in priming where animacy-semantic role mappings are prototypical and matching across primes and target pairs will decrease with age.

Method

Design

We used a 3x2x2x2 mixed design. Age (3 years/5 years/adults) and prime structure (double-object dative [DOD]/prepositional dative [PD]) were between-subject independent variables. Prime animacy-semantic role mappings (prototypical [AN goal & IN theme]/ non-prototypical [AN theme & IN goal] and prime-target match in animacy-semantic role mappings (match/mismatch) were within-subjects independent variables. The production of DOD target responses was our dependent variable.

Participants

We tested 143 monolingual British English speakers; 47 three year olds (24 females), 48 five year olds (25 females), and 48 adults (35 females). One three year old was excluded for their failure to produce any dative sentences.

Visual Stimuli

Sixty-eight 10-second animations were created in *Anime Studio Pro 10* and presented on a laptop using Microsoft PowerPoint. Forty-eight (24 for primes and 24 for targets) portrayed ditransitive events (e.g. a girl bringing a monkey a ball). Twenty depicted intransitive events featuring two characters simultaneously acting in the centre of the screen (e.g. a boy and girl jumping). Eight of these were used as practice scenes (four each for the experimenter and participant) and 12 were used as fillers (six each).

Sentence Stimuli

Eighty- two sentences were created as descriptions for the 68 animations. These included:

- Practice Items (4): Intransitive sentences for the experimenter's turn in practice trials to introduce participants to the task.
- Fillers (6): Present-tense intransitive sentences for the experimenter's turn in filler trials to limit priming effects across prime-target pairs.
- Primes (48): Past tense dative sentences which included 24 DOD and 24 PD counterparts corresponding to the 24 prime scenes. Six different prime sentences were assigned to each of the four experimental conditions.
- Targets (24): Six different verbs were included in sentence initiations for target sentences (e.g. *the boy brought*). Primes and targets always contained the same verb and participants completed these sentence initiations to produce the full target sentence. See Table 1 for example prime sentences and target elicitation scenes.

Procedure

The experimenter played the animations on a laptop, beginning with four *practice-practice* trials, followed by alternating *prime-target* and *filler-filler* trials. She described the first scene and produced the first sentence in each pair, producing all primes and participants described the second scene in each pair, including all targets. On target trials, the experimenter produced initial sentence initiations (e.g. *the girl brought…*) to encourage participants' use of datives. Participants formed their own target structures as they finished the sentence (e.g. *the monkey a ball* or *the ball to the monkey*). Adult participants often produced entire target sentences including the initial subject and verb.

Table 1: Example prime sentences and target elicitation scenes for each condition

Condition	DOD Prime	PD Prime	Target Elicitation Scene
Prototypical Prime (AN goal & IN theme) / Matched Target	*The girl brought the monkey a ball*	*The girl brought a ball to the monkey*	Transfer of a flower from boy to a snail
Prototypical Prime (AN goal & IN theme) / Mismatched Target	*The girl brought the bee a flower*	*The girl brought a flower to the bee*	Transfer of a monkey from a boy to a zoo
Non-prototypical Prime (AN theme & IN goal) / Matched Target	*The girl brought the zoo a tiger*	*The girl brought a tiger to the zoo*	Transfer of a bee from a boy to a zoo
Non-prototypical Prime (AN theme & IN goal) / Mismatched Target	*The girl brought the garden a snail*	*The girl brought a snail to the garden*	Transfer of a ball between a boy and a tiger

Coding

Target responses were coded for syntactic structure (double-object dative [DOD], prepositional dative [PD] and OTHER). Only DOD and PD target sentences were included in the analyses.

DOD: sentences with a *goal – theme* structure (e.g. *the boy brought the tiger a ball*).

PD: sentences with a *theme – preposition - goal* structure (e.g. *the boy brought a tiger for the monkey*). Both *to* and *for* were suitable prepositions.

OTHER: Such responses were excluded from the analyses and included:

1. Sentences without a DOD or PD structure (e.g. intransitive and/or incomplete sentences with only one noun such as *the boy threw the whale,* or locatives such as *the boy threw the way into the sea*).
2. Incomplete sentences with one object and a preposition but no second object (e.g. *the boy threw the food to)*
3. Sentences where nouns were assigned to the wrong semantic role (e.g. *the boy brought the ball* [goal] *a tiger* [theme], where the target scene actually showed the transfer of a ball [theme] between a boy and tiger [goal]. A misunderstanding of the target scene may influence target structures where animacy cues might interact with syntactic structures.
4. Sentences with incorrectly named nouns, indicating participant's misunderstanding of the event shown in the target scene (e.g. *the boy brought the zoo/mouse a ball* instead of *the boy brought the tiger a ball*).

The percentage of OTHER target responses was 38% in three year olds, 28% in five year olds and 27% in adults. This is to be expected because although our events involved three participants, it is perfectly acceptable to focus on only a subset of these in a linguistic description of the scenes.

Results

The data were analysed using logistic mixed effects models in R, using the glmer function of the lme4 package (lme4 version 1.1-11: R Core Team 2012). Fixed effects for all final models included: age (3 years = -1; 5 years = 0; adult = 1), prime animacy-semantic role mappings (prototypical [AN theme – IN goal] = 1; non-prototypical [IN theme – AN goal] = 0) and prime-target match in animacy-semantic role mappings (match = 1; mismatch = 0). All variables were centred to reduce multicollinearity (Neter, Wasserman & Kuttner, 1985). Participant was always included as a random effect. Sentence item was excluded as a random effect and the analyses were separated by age since the model initially fitted to the full data set did not converge. For each individual age group, the Bonferroni method was used with a corrected alpha level of .025 for post-hoc analyses. The mean proportion of DOD target responses produced in each condition is shown in Figure 1.

Age Three

The model initially contained only main effects of prime structure, prime animacy-semantic role mappings and prime-target match, but was significantly improved by adding a three-way interaction term and all the two-way interaction terms that are derived from it (p = .03). We found a significant main effect of prime structure whereby more DOD targets were produced following DOD (*M* = 0.27, *SE* = 0.02) as opposed to PD primes (*M* = 0.06, *SE* = 0.01) and a significant three-way interaction between prime structure, prime animacy-semantic role mappings and prime-target match.

To interpret the three-way interaction a model was fitted for each level of prime structure (DOD and PD). Analysis of DOD primes failed to reveal any significant effect for prime animacy-semantic role mappings, β = 0.20 (*SE* = 0.31), *z* = 0.65, *p* = .518, prime-target match, β = -0.12 (*SE* = 0.31), *z* = -0.40, *p* = .688, or the interaction between the variables, β = 0.61 (*SE* = 0.61), *z* = 1.02, *p* = .31. Analysis of PD primes, however, revealed a significant two-way interaction between prime animacy-semantic role mappings and prime-target match, β = 3.89 (*SE* = 1.39), *z* = 2.81, *p* = .005.

Two further models were run for PD primes, one for each level of animacy-semantic role mapping (prototypical [AN goal & IN theme]/non-prototypical [AN theme & IN goal]). Where PD primes featured non-prototypical animacy-semantic role mappings, there was a marginally significant effect of prime-target match, β = -2.33 (*SE* = 1.07), z = -2.19, p = .029. Fewer DOD responses were produced where targets contained matched (non-prototypical) animacy-semantic role mappings (*M* = 0.01, *SE* = 0.03) as opposed to mismatched (prototypical) animacy-semantic role mappings (*M* = 0.11, *SE* = 0.03). However, where PD primes contained prototypical animacy-semantic role mappings there was no significant effect of prime-target match, β = 1.47 (*SE* = 0.85), *z* = 1.73, *p* = .08.

Age Five

The model originally featured only main effects but was significantly improved by adding two-way interaction terms between the variables (*p* = .007). There was a significant main effect of prime structure whereby more DOD targets were produced following DOD (*M* = 0.30, *SE* = 0.02) as opposed to PD primes (*M* = 0.02, *SE* = 0.01) and a significant two-way interaction between prime animacy-semantic role mapping and prime-target match β = 1.15 (*SE* = 0.51), *z* = 2.28, *p* = .002.

To interpret the two-way interaction, a model was fitted for each level of prime animacy-semantic role mapping (prototypical [AN goal & IN theme]/non-prototypical [AN theme & IN goal]). For prototypical prime animacy-semantic role mappings there was a significant effect of prime-target match, β = 0.83 (*SE* = 0.35), *z* = 2.35, p = .018. DOD production was higher where targets featured matched (prototypical; *M* = 0.18, *SE* = 0.02) as opposed to mismatched (non-prototypical; *M* = 0.09, *SE* = 0.02) animacy-semantic role mappings. However, where primes contained non-prototypical animacy-semantic role mappings there was no effect of prime-target match, β = -0.48 (*SE* = 0.36), *z* = -1.35 *p* = .177. There was no difference in the production of DOD targets where targets featured matched (non-prototypical; *M* = 0.14, *SE* = 0.03) as compared with mismatched (prototypical; (*M* = 0.09, *SE* = 0.03) animacy-semantic role mappings.

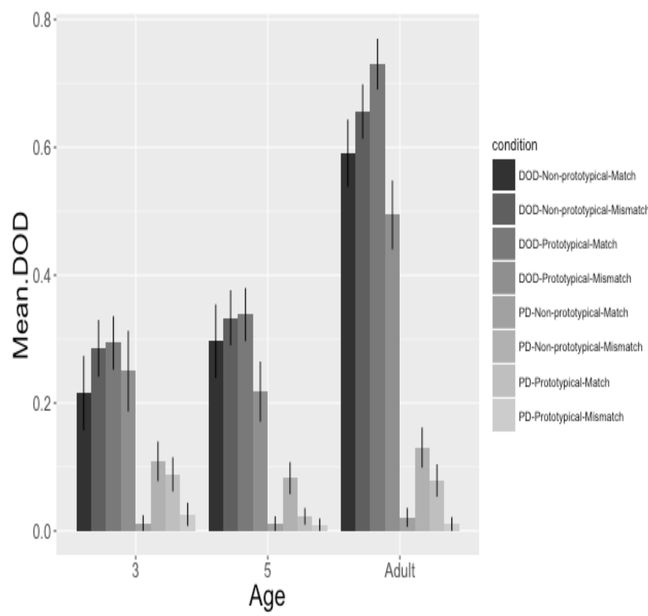

Figure 1: The mean proportion of DOD responses following DOD and PD primes where primes contained either prototypical or non-prototypical animacy-semantic role mappings and these mappings were either matched or mismatched across primes and targets (*SE* in error bars).

Adults

The model originally featured only main effects but was significantly improved by adding two-way interaction terms between the variables (*p* < .001). We found a significant effect of prime structure with more DOD targets produced following DOD (*M* = 0.64, *SE* = 0.02) than PD primes (*M* = 0.07, *SE* = 0.12) and a significant two-way interaction between prime animacy-semantic role mapping and prime-target match.

To interpret the two-way interaction a model was fitted for each level of prime animacy-semantic role mapping (prototypical [AN goal & IN theme]/non-prototypical [AN theme & IN goal]). For primes with prototypical animacy-sematic role mappings we found a significant effect of prime-target match, β = 2.608 (*SE* = 0.51), *z* = 5.09, *p* < .001. DOD production was higher where targets featured matched (prototypical; *M* = 0.43, *SE* = 0.03) as opposed to mismatched (non-prototypical; (*M* = 0.25, *SE* = 0.03) animacy-semantic role mappings. Where primes contained non-prototypical animacy-semantic role mappings, there was also a significant effect of prime-target match β = -1.33 (*SE* = 0.43), *z* = -3.12, *p* < .001. Fewer DOD responses were produced where targets contained matched (non-prototypical; *M* = 0.30, *SE* = 0.03) as opposed to mismatched (prototypical; (*M* = 0.40, *SE* = 0.03) animacy-semantic role mappings.

Results Summary

All age groups showed an effect of structural priming, producing more DOD responses following DOD primes, as compared to PD primes. Three year olds also exhibited effects of animacy-semantic role mappings on the magnitude of structural priming, showing an increase in PD sentence priming effects where primes and targets contained matching non-prototypical mappings (AN theme & IN goal) (although no effects were observed for DOD primes). Our hypothesis that priming would be greater with prime-target match was met, indicating that animacy mappings were represented to a relatively strong degree. However, priming increased with non-prototypical rather than prototypical primes providing support for error-based learning accounts. As expected, animacy effects decreased with age; they had no influence on structural priming in five year olds or adults. Nevertheless, animacy did influence DOD target production in five year olds and adults, independently of prime structure. They produced more DOD sentences where targets (and also primes in the case of five year olds) contained prototypical animacy-semantic role mappings (AN goal & IN theme).

Discussion

Our results support claims of structural priming effects in children (Rowland et al., 2012) and adults (Bock, 1986) and more importantly, they provide further clarification as to how structural priming works. Our results reveal that priming relies, first and foremost, on the repetition of abstract syntactic frames and not the repetition of animacy noun orders. This was previously unclear due to methodological issues with earlier research (Chang, Bock & Goldberg, 2003). Non-prototypical (AN theme & IN goal) DOD primes with an inanimate-animate noun order (e.g. *the girl brought the zoo a monkey*) were just as likely to yield DOD targets as prototypical (AN goal & IN theme) DOD primes with an animate-inanimate noun order (e.g. *the girl brought the monkey a ball*). Mere repetition of animacy noun ordering would have resulted in more prototypical PD targets with an inanimate-animate noun order (e.g. *the girl brought the flower to the* snail) following non-prototypical DOD targets. All age groups showed a main structural priming effect, suggesting that children's linguistic representations do not need to specify animacy-semantic role mappings for priming to occur.

PD sentence priming was enhanced in three year olds where there was prime-target match in non-prototypical (AN theme & IN goal) animacy-semantic role mappings. This is consistent with Gámez and Vasilyeva's (2015) finding that prime-target match increased priming in five and six year olds. Our results are thus at odds with Pickering and Branigan's (1998) residual activation theory as it cannot explain how semantic information could influence structural priming. We found that animacy-semantic role mappings were specified and represented to a relatively strong degree and could influence priming through error-based learning in support of Chang, et al (2006). We suggest that error-based learning may have been less likely to occur following DOD primes as three year olds generally use fewer DOD than PD constructions (Rowland, et al., 2012). They might not have been sensitive enough to the typical animacy mappings in DOD sentences for surprisal priming effects to occur.

Five year olds and adults showed no evidence of increased priming where primes contained non-prototypical (AN theme & IN goal), as opposed to prototypical (AN goal & IN theme) animacy-semantic role mappings. This developmental decrease in error-based learning may be due to increased exposure to such lower frequency sentence types and is consistent with Rowland, et al., (2012) and Peter, et al.'s (2015) results. Our results also complement those of Corrigan (1988) who found animacy effects on children's sentence interpretations to decrease with age.

Nevertheless, five year olds and adults produced more DOD targets where targets (and also primes for five year olds) contained prototypical (AN goal & IN theme) mappings, regardless of prime structure. This indicates a preference to use animate goals and inanimate themes in DOD as opposed to PD constructions. These data therefore support claims that animacy interacts with semantic role-grammatical function mappings and can influence subsequent word order (Zorzi & Vigliocco, 1999; Goldberg, 1995; Garrett, 1975). Animate goals tended to be realised as indirect objects more than as oblique objects and were often placed before inanimate theme-direct objects, resulting in DOD constructions (e.g. *brought the monkey* [animate goal] *a ball* [inanimate theme]).

Speakers' tendency to encode animate goals and inanimate themes in DOD constructions increased with age. Very small surprisal effects may have moderated five year olds' DOD production. Non-prototypical (AN theme & IN goal) PD primes may have subtly increased PD sentence priming through error-based learning. Non-prototypical DOD primes may have sometimes primed participants to reuse noun animacy orders in prototypical PD constructions. E.g. the DOD prime *the girl brought the zoo* [inanimate] *a monkey* [animate] could have prompted the PD response *the boy brought the ball* [inanimate] *to the tiger* [animate]).

We should however, also seek to clarify whether animacy could influence word orders in sentence production independently of syntax and/or grammatical roles. Bock, Loebell and Morey (1992) provide evidence to suggest that this is possible. Following primes with animate subjects before inanimate objects, participants were more likely to produce targets with the same noun animacy order than an inanimate subject-animate object order. It did not matter whether subjects were agents or patients of active or passive sentences. Little research has been conducted to address this topic in adults and it is yet to be explored in children.

Conclusion

In our study animacy-syntax interactions appeared to facilitate structural priming in young children but this effect was subject to a developmental decrease. The extent to which animacy-semantic role mappings could influence speakers' choice of syntactic structure independent of structural priming, rather increased with age. Animacy-syntax interactions can therefore influence sentence production. We consequently propose that theories of structural priming and sentence production in general should seek to consider the role of animacy-syntax interactions.

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References

Ambridge, B., Kidd, E., Rowland, C. & Theakston, A. (2015). The ubiquity of frequency effects in first language. *Journal of Child Language*, *42(2),* 239-273.

Bock, J. K. (1986). Meaning, sound, and syntax: Lexical priming in sentence production. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *12*(4), 575.

Bock, K., Dell, G. S., Chang, F., & Onishi, K. H. (2007). Persistent structural priming from language comprehension to language production. *Cognition*, *104*(3), 437-458.

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

Bresnan, J., Cueni, A., Nikitina, T., & Baayen, R. H. (2007). Predicting the dative alternation. *Cognitive foundations of interpretation*, 69-94.

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.

Cleland, A. A., & Pickering, M. J. (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*(2), 214-230.

Corrigan, R. (1988). Children's identification of actors and patients in prototypical and nonprototypical sentence types. *Cognitive Development*, *3*, 285–297.

de Swart, P., Lamers, M., & Lestrade, S. (2008). Animacy, argument structure, and argument encoding. *Lingua*, *118*(2), 131-140.

Demuth, K., Machobane, M., Moloi, F., & Odato, C. (2005). Learning animacy hierarchy effects in Sesotho double object applicatives. *Language*, 421-447.

Gámez, P. B., & Vasilyeva, M. (2015). Exploring interactions between semantic and syntactic processes: The role of animacy in syntactic priming. *Journal of Experimental Child Psychology*, *138*, 15-30.

Garrett, M.F. (1975). The analysis of sentence production. In G.H. Bower (Ed.), *The psychology of learning motivation*. New York: Academic Press.

Goldberg, A. E. (1995). *Constructions: a construction grammar approach to argument structure*. University of Chicago Press, Chicago, IL.

Goldwater, M. B., Tomlinson, M. T., Echols, C. H., & Love, B. C. (2011). Structural priming as structure Mapping: Children use analogies from previous utterances to guide sentence production. *Cognitive Science*, *35*(1), 156-170.

Levelt, W. J., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and brain sciences*, *22*(01), 1-38.

Neter, J., Wasserman, W., & Kutner, M. H. (1985). *Applied linear statistical methods*. Richard D. Irwin. Inc., Homewood, IL.

Peter, M., Chang, F., Pine, J. M., Blything, R., & Rowland, C. F. (2015). When and how do children develop knowledge of verb argument structure? Evidence from verb bias effects in a structural priming task. *Journal of Memory and Language*, *81*, 1-15.

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.

R Core Team (2012). *R: A language and environment for statistical computing*. 3-900051-07-0. Vienna, Austria: R Foundation for Statistical Computing

Rowland, C. F., & Noble, C. L. (2010). The role of syntactic structure in children's sentence comprehension: Evidence from the dative. *Language Learning and Development*, *7*(1), 55-75.

Rowland, C. F., Chang, F., Ambridge, B., Pine, J. M., & Lieven, E. V. (2012). The development of abstract syntax: Evidence from structural priming and the lexical boost. *Cognition*, *125*(1), 49-63.

Zorzi, M., & Vigliocco, G. (1999). Compositional semantics and the lemma dilemma. *Behavioral and Brain Sciences*, *22*(01), 60-6