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ANTECEDENT TOPICALITY AFFECTS THE PROCESSING OF BOTH NP ANAPHORS AND PRONOUNS

by

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ABSTRACT

Information structure and grammatical constraints are known to affect the salience of discourse referents and referential processing, but it is not clear whether the two types of constraints have comparable effects. We report two visual-world experiments that contrasted the effect of a grammatical constraint (subjecthood) and the effect of an information structure constraint (fronting) on processing noun and pronoun anaphors. Experiment 1 tested whether fronting a non-subject referent can eliminate the Repeated Name Penalty (RNP; Gordon et al., 1993) when referring to the subject. Experiment 2 tested whether fronting a non-subject referent can elicit the RNP. The results show that fronting can eliminate the RNP and also elicit an effect that is similar but not identical to the RNP. Overall, this study shows that information structure constraints and grammatical constraints can have comparable effects on reference processing but these effects are not identical in their magnitude and specific time course. More generally, this study shows that pronouns and nouns are not processed in a complementary fashion, and that the RNP is not a single simple effect, but might instead be a family of related effects that occur in different time frames.

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List of Abbreviations

ASL……………………………………………………Applied Science Laboratories

CB……………………………………………………Backward Looking Center

CB(Un)……………………………Backward Looking Center of the Current Utterance

CB (Un-1)…………………………..Backward Looking Center of the Previous Utterance

CF…………………………………………………....Forward Looking Center

CF(Un)………………………………Forward Looking Center of the Current Utterance

CF(Un-1)……………………………...Forward Looking Center of the Previous Utterance

GCA…………………………………………………. Growth Curve Analysis

MS……………………………………………………..Milliseconds

NP……………………………………………………...Noun Phrase

RNP……………………………………………..Repeated Name Penalty

USC………………………………………..University of South Carolina

Un……………………………………………………...Current Utterance

Un-1……………………………………………………Previous Utterance

USC………………………………………..University of South Carolina

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CHAPTER 1 – INTRODUCTION

Coherent linguistic communication often contains repeated references to referents that have been mentioned before. These references often take the form of a proper name, definite description, or pronoun. There is substantial evidence showing a connection between reference form and the degree of salience of the referent in the discourse (Givón, 1983; Ariel, 1990; Vonk, Hustinx & Simons, 1992). Several factors such as order of mention, focus, subjecthood, and topicality have been shown to contribute to the salience of referents in the discourse (Bezuidenhout, Morris & Bousman, 2009; Arnold, Eisenband, Brown-Schmidt & Trueswell, 2000; Gernsbacher and Hargreaves, 1988; Jarvikivi, Van Gompel, Hyona & Bertram, 2005). These factors can be divided into two general types: grammatical-surface constraints, such as subjecthood and order of mention, and information structure constraints, such as topicality. Much research has focused on the effects of grammatical-surface constraints on referential processing, some research examined the effects of information structure constraints, but only a little research has looked into the interaction of the two types of constraints. The present work, therefore, aims to examine how an information structure constraint interacts with a powerful grammatical-surface constraint, grammatical subjecthood, in the processing of noun and pronoun references.

In one of the most influential studies of discourse information structure, Reinhart (1982) linked the notion of topicality with the concept of sentence topic ("what the sentence is about"). Reinhart and others defined topicality in terms of an "aboutness

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condition": the topic of a proposition expressed by an utterance is what the proposition is about, given a particular situation (e.g., Reinhart, 1982; Lambrecht, 1994). A slightly different approach linked the notion of topic to the mental representation of the discourse by the speaker and the addressee. According to Accessibility theory (Ariel, 1990), a topic is identified based on its high availability to the addressee. Gundel (1976) similarly suggests that shared knowledge and high familiarity of the entity to both the addressee and the speaker account for topic status. Thus, according to these approaches, topic is identified as the most salient entity in the mental representations of both the speaker and the addressee. Reainhart's, Ariel's and Gundel's accounts assume that topic is a categorical notion: the entity can either be or not be a topic and there is only one topic in each unit of discourse (sentence or utterance). Considering that in English the most important entity in the discourse is usually mentioned in the subject position, which is also the first position in the sentence, it is not surprising that topicality has been frequently confounded with subjecthood (Cowles, 2007).

Indeed it is grammatical subjecthood rather than topicality that has been most often associated with increased referent salience (e.g., Reinhart, 1982; Crawley & Stevenson, 1990; Gordon et al, 1993). For example, Crawley and Stevenson (1990) conducted a sentence completion study that showed that participants tended to continue sentences such that pronouns referred back to the preceding grammatical subject more often than to any other entity. Because pronouns are typically used to refer to the most salient entities, this shows that grammatical subjects tend to be the most salient referents. Perhaps the strongest empirical demonstrations of the contribution of subjecthood to referent salience comes from Gordon et al. (1993) who showed that names are harder to

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process than pronouns when they refer back the subject of the previous sentence. These investigators labeled this effect the repeated name penalty (RNP).

The work of Gordon et al. (1993) is based on Centering theory (Grosz et al., 1995), which is a computational account of reference processing that aims to explain how different referential expressions maintain coherence within a discourse segment. In that approach, all entities in an utterance belong to a set of forward looking centers (Cf) ranked by order of salience in the discourse. Each utterance also contains one backward-looking center (Cb) that connects the utterance (Un) to the previous utterance (Un-1) by being co-referential with one Cf (Un-1). According to Centering theory, the coherence of the discourse is affected by this connection.

Centering theory distinguishes between four types of discourse transitions based on the connection between a Cb and the Cf's of the current and previous utterances. A "Continue" transition is the most preferable type of transition in terms of attention demands and discourse coherence. This type of transition holds when the Cb (Un-1) is also the Cb (Un), and Cb (Un) is the most salient Cf (Un). A "Retain" transition holds when the Cb (Un-1) is also the Cb (Un), but Cb (Un) is no longer the most salient Cf (Un). A "Smooth Shift" transition holds when the Cb (Un-1) is different from the Cb (Un), but the Cb (Un) is the most salient Cf (Un). Finally, a "Rough Shift" transition holds when the Cb (Un-1) is different from the Cb (Un), and the Cb (Un) is not the most salient Cf (Un).

Centering theory further argues that backward looking centers are usually mentioned in the subject position of utterances, and preferably by pronouns rather than repeated names. When this preference is violated, discourse coherence is interrupted. The

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RNP found by Gordon et al. (1993) was interpreted as a verification of this prediction. Although Centering theory and this interpretation of the RNP have been critiqued by other researchers (e.g., Almor, 1999), there is agreement that the RNP constitutes a good test of referent salience. Indeed, using the RNP as an index of salience, Gordon et al. (1993) found that references to non-subjects can also elicit the RNP. Consider the following discourse taken from Gordon et al. `s (1993) Experiment 5:

1. Sue bought Fred a pet hamster.
2. In his opinion, she shouldn't have done that.
3. Fred/He doesn't have anywhere to put a hamster cage.

Gordon et al. (1993) found an RNP in Sentence 3 which they attributed to order of mention. According to their explanation, the fronting parenthetical "in his opinion" placed the non-subject referent first, and thus increased its salience sufficiently to elicit the RNP. However, order of mention may not be the only reason for the increased salience of the non-subject. In particular, Bezuidenhout et al. (2009) argued that the RNP for the non-subject referent found by Gordon et al.'s study is a result of the influence of information structure rather than the order of mention. They theorized that if the information conveyed by the fronted phrase is subordinate to the meaning of the main clause, the entity referred to in the fronted phrase will not be raised in salience and will not elicit the RNP when mentioned by the repeated name. However, if the information conveyed by the fronted phrase contributes substantially to the understanding the meaning of the main clause (as in sentence 2 above), then the fronted entity will be raised in salience and will elicit the RNP when mentioned by the repeated name. To test their explanation, Bezuidenhout et al. (2009) conducted a self-paced reading experiment that

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manipulated the information status of the fronted phrase. Consistent with their hypothesis, they found that different types of fronted phrases have different impact on the salience of the entities mentioned in those phrases. This means that the RNP for the non-subject entities reported by Gordon et al. (1993) could not be accounted for by just the order of mention.

Overall, Centering theory and the empirical work following it offer an elaborate model of referential processing and provide a useful terminology to classify discourse transitions. However, despite the descriptive usefulness of Centering terminology, Centering theory does not account for the effects of multiple constraints that influence referential processing. In particular, demonstrations of the importance of information structure (Bezuidenhout et al., 2009) as opposed to surface structure and grammatical factors (Gordon et al., 1993), suggest that more work is needed in order to understand how information structure factors affect the salience of the referents in the discourse. In our study we will use Centering terminology to describe relationships between utterances, but will assume a broader information processing perspective.

Importantly, the explanation of Bezuidenhout et al. (2009) is based on the relative prominence of the referent in the information structure representation of the discourse. Their study therefore shows that information structure can affect reference processing changing the preferences for different referential forms. Another study is Cowles (2007a) who examined the influence of "about-constructions" on the salience of non-subject referents (e.g., a nurse noticed something about the lightning). She found that participants identified the entity in the about-phrase (the lightning) as the topic more often than the entity in the subject position (the nurse). Similar to Bezuidenhout et al. (2009), Cowles`s

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study shows that information structure constraints affect the salience of referents. However, it is still unclear how such information structure constraints interact with the more frequently studied grammatical constraints.

The aim of the present study was therefore to test the interaction of an information structure constraint and a grammatical constraint during reference comprehension. Because we were interested in the time course of this interaction, we employed the visual-world paradigm (Tanenhaus, Spivey-Knowlton, Eberhard & Sedivy, 1995). One of the crucial features of the visual-world paradigm is that it provides a continuous measure of spoken language processing which is not interrupted by the speech stream or by a secondary task. This makes this paradigm ideal for investigating the role of multiple constraints on discourse and reference comprehension.

We conducted two experiments that examined how information structure interacts with subjecthood in the processing of repeated name and pronoun references. To manipulate information structure, we used pre-sentential fronted phrases similar to those used by Gordon et al. (1993) & Bezuidenhout et al. (2009) (e.g., "In his opinion …"). Fronted phrases provide a good means to assess the impact of information structure on referent salience without confounding it with subjecthood. To gauge referent salience, we tested the processing of both repeated name and pronoun anaphors. Our experiments aimed to answer the following questions: (1) are the two factors comparable in terms of their impact on salience of entities and on subsequent reference resolution? (2) Does the stronger factor completely override the effect of the other, or do they combine in a specific time course?

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Experiment 1 tested whether our fronting manipulation can decrease the Repeated Name Penalty for subject antecedents. Experiment 2 tested whether fronting is a powerful enough salience enhancer to elicit a Repeated Name Penalty for non-subject antecedents.

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CHAPTER 2 – EXPERIMENT 1

Experiment 1 was designed to assess the effect of fronting on the processing of repeated name and pronoun references to grammatical subject antecedents. We tested whether fronting, a potential information structure salience enhancer, can counter the effect of subjecthood, a well-established grammatical salience enhancer. We looked at the processing of repeated name and pronoun anaphors to see whether fronting can eliminate the RNP.

We constructed three sentence discourses in which each sentence contained references to two interacting animate referents. One referent (the Target) was established as the most salient entity in the discourse by mentioning it in the subject position of all three sentences. Information structure was manipulated by referring to either the Target or the other entity (the Interactor) in a fronted parenthetical phrase at the beginning of the second sentence. We aimed to test whether referring to the Interactor can override the effect of grammatical salience as indicated by the RNP. To this end, we contrasted repeated name references (Noun conditions) and pronoun references (Pronoun conditions) to the Target in the third sentence. In the Continue conditions the Target was also the fronted entity in Sentence 2, thus ensuring that it remains the most salient entity. In the Retain conditions, the Interactor was the fronted entity, thus possibly reducing the salience of the Target by the fronting. For each experimental condition we examined the proportions of fixations to pictures of the two mentioned entities (the Target and the

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Interactor) as well as to a picture of a referent that was similar to the Target except for one distinctive feature (the Distractor). There was also a fourth picture of an unrelated object (the Unrelated). Sample item is shown in Table 1 and Figure 1.

We expected an RNP in the Continue conditions and predicted that if information structure were a powerful salience enhancer, fronting of the non-subject antecedent would decrease or eliminate the RNP in the Retain conditions. The RNP should be reflected by continued engagement of the Target, delayed engagement of the Interactor, and possibly more looks to the Distractor. Therefore, we predict more differences between the Continue Noun and the Continue Pronoun conditions than in the in Retain Noun and the Retain Pronoun conditions.

2.1 METHODS

Participants

Fifty-six participants attending Psychology classes in USC served as subjects. They were all native speakers of American English and participated in the study for extra credit.

Materials

We constructed 24 three-sentence discourses that described an interaction between two animate protagonists. We manipulated whether or not a non-subject Target referent was mentioned in the adverbial fronted phrase. Table 1 shows a verbal item in all conditions. Sentence 1 described an interaction between the Target and the Interactor. The Target referent appeared in the subject position and the Interactor referent appeared in the object position with a prepositional phrase modification identifying its distinctive

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feature. The distinctive feature indicated which of the depicted objects was the one mentioned in the sentence. Sentence 2 started with an adverbial fronted phrase with a pronominal reference to either the Interactor or the Target. The rest of Sentence 2 included a pronominal reference to the Target in the subject position and no additional mention of the Interactor. Sentence 3 mentioned the Target in the subject position using either a noun or pronoun. The Interactor was mentioned in the object position using a noun. Thus, Sentence 1 established the Target as the most salient referent through first mention in the subject position, and Sentence 2 maintained the Target as the salient referent through pronominal reference in the subject position. However, Sentence 2 also included a fronting manipulation that, in the Retain conditions, could have increased the salience of the Interactor and reduced the salience of the Target.

The discourses were recorded by a native English speaker. We paired the discourses with visual displays that depict an animate Interactor, an animate Target, a Distractor similar to the Target except for one distinctive feature, and an inanimate object that is somehow related to the scene described in the discourse. The Interactor and Target had different genders in order to avoid referential ambiguity when processing subsequent pronoun references. The inanimate object that appeared on the screen along with the Target, Interactor and Distractor was not mentioned in the discourse the participant heard. There were 24 experimental items and 24 fillers. The pictorial displays were created by taking pictures of PlayMobil toys.

Procedure

Participants were seated at the computer and then asked to position their head in the chin rest. They then read the instructions on the screen. The experimenter then

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repeated the instructions to ensure that they were understood by the participant. Participants were instructed to look at the display and then click a mouse button in order to start the trial. They then heard the discourse, which ended with a question that they answered by clicking on an object in the pictorial display that was the correct answer. Sentence 3 was the critical sentence. Participants' eye movements were recorded as they listened to the entire discourse but only the eye movement data from the critical sentence were analyzed. All participants responded with accuracy greater than 80%. Because this indicates that participants were processing the discourse, and because the focus of this experiment was on online processing, the clicking responses were not analyzed further.

We used an ASL 6000 eye tracker with a chin rest connected to a testing computer running the e-Prime software. Eye movement data was recorded at a 250 Hz sampling rate. Calibration was performed at the beginning of the experiment and then verified and, if necessary, adjusted every four trials.

Data analysis

Growth curve analysis (GCA) with orthogonal polynomials was used to analyze differences in the fixation time course for noun and pronoun references in the different discourse conditions (Mirman, Dixon, & Magnuson, 2008). This statistical technique was chosen because it allows for a precise assessment of the fine-grained continuous data. Conventional statistical techniques describe such data in terms of single numbers that represent mean fixation proportion in a single window of analysis (Allopenna, Magnuson & Tanenhaus, 1998). However, determining a specific time window that would accurately capture change over time is problematic because different time windows produce different results and there is no a-priori criterion for selecting an optimal time

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window. Furthermore, performance within time windows is not always consistent. Because we were interested in how multiple factors interact over time, we needed an approach that would allow us to examine eye-movement dynamics with maximum precision.

Our GCA contained two levels: the first level captured the effect of time on the fixations of participant, and the second level captured the effect of experimental conditions on the time course of the different orders. The effects of subjects on the intercept and all of the time terms were included in the model as random factors, and this variation is captured in the second level.

We first fit the data with a base model which included only the time coefficients but not the effects of conditions. We then added the interaction of the conditions with the intercept and the linear, quadratic, cubic and quartic time terms. We then used both an AIC evidence based method (Forster & Sober, 1994, 2011; Long, 2012) and maximum likelihood to compare the models in order to determine the necessary time order of the model. After selecting the best fitting full model with the smallest time order, we gradually started to remove high-order terms from that model in an attempt to find the simplest best-fitting model. The best fitting model was chosen according to a criterion that optimizes model fit and number of degrees of freedom. The chosen model was thus the simplest model that fit the data no worse than any of the more complex models. Our focus here is on whether the simplest model included the interaction effects involving discourse and reference and any of the time terms. The effects of experimental conditions

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are examined in relation to the chosen model and evaluated based on the model`s parameters and a visual inspection of the shape of the fitted curve. For each analysis, we present a table and a graph with the results of model comparison, the chosen model`s parameters, and a graph of the observed data with an overlay of the chosen growth curve model.

2.2 RESULTS

Ten participants who failed to maintain calibration during the procedure were excluded from further analysis. Eye position data from the remaining forty-six participants were transformed into fixations using the ASL Results software following the procedure recommended by Lambert, Monty and Hall (1974). Fixations were matched with the E-prime data in order to determine the item, condition and position of the different pictures on the screen for each trial as these were assigned randomly during the session. Proportions of fixations to the Target, the Distractor, the Interactor and the Unrelated object in successive 25 ms windows were the dependent variables for the growth curve analyses (GCA) described below. Because our focus was on the RNP, we looked for the differences in the 1500 ms time window following the offset of the mention of the Target in Sentence 3.

Fixations to the Target

To examine whether fronting of the non-subject referent affected the processing of the subject referent and, in particular, decreased the RNP, our first CGA examined the proportion of fixations to the Target in the four conditions. The results of the model comparisons are shown in Tables 2 and 3. Figure 2 shows the proportion of fixations to

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the Target and the fit estimate lines for the best fitting model. The best fitting model included an interaction between Discourse and Reference on the linear, quadratic, and cubic time terms. As can be seen in Figure 2, this effect was due to a quicker rate of disengaging the Target in the Continue Pronoun condition in comparison to the Continue Noun condition. There were no differences in processing the Target between the Retain Noun and the Retain Pronoun conditions.

Fixations to the Interactor

To examine whether our fronting manipulation made the repeated NP easier to process, our next GCA contrasted the proportion of fixations to the Interactor in the four conditions. If fronting the non-subject referent does not change the magnitude of the RNP for the subject referent, then there should be no differences between the Retain and Continue conditions in fixations to the Interactor. The results of the model comparisons are shown in Table 4 and 5, and the best fitting model is shown in Figure 3. The best fitting model included an interaction between Discourse and Reference on the linear and quadratic time terms. As is shown in both tables and figure, this interaction was driven by the quickest rate of engaging the Interactor in the Continue Pronoun condition.

The analyses reported so far indicate an RNP in the Continue conditions and a reduction of the RNP in the Retain conditions. Our next analyses aimed to understand the role of the other potential referents in this reduction.

Fixations to the Distractor

We conducted similar GCAs on fixations to the Distractor. If the RNP is related to the consideration of other referents, and if fronting eliminates the RNP (as indicated by looks to the Target and the Interactor), then there should be more looks to the Distractor

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in the Continue Noun condition than in the other conditions. The results of the model comparisons are shown in Tables 6 and 7, and the best fitting model is shown in Figure 4. The best fitting model included an interaction between Discourse and Reference on the quadratic and cubic time terms. This interaction was largely due to an initial engagement of the Distractor in the Retain Pronoun condition that was then followed by a strong disengagement. There was also an accelerated and sustained engagement of the Distractor in the Continue Noun condition, but this was only slightly different than the Retain Noun and Continue Pronoun conditions, in which the engagement of the Distractor started a little later. Thus, the RNP in the Continue condition was associated with an initial consideration of the Distractor and the elimination of the RNP in the Retain conditions was associated with a different effect to which we return in the Discussion section.

Fixations to the Unrelated object

To examine whether fixations to the Distractor were related to its animacy and similarity to the Target, we also conducted GCA on fixations to the Unrelated object. The results of the model comparisons are shown in Tables 8 and 9, and the best fitting model is shown in Figure 5. The best fitting model included an interaction between Discourse and Reference on the quadratic term. This effect is likely driven by increased engagement of the Unrelated object in the Retain Pronoun condition and decreased engagement of the Unrelated object in the Retain Noun condition. Although the small number of fixations to both the Distractor and the Unrelated object prevents making strong claims, the patterns of fixations to the two objects appear quite different. It therefore seems that animacy and/or the relation to the Target affects reference processing.

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2.3 DISCUSSION

Experiment 1 elicited the RNP for the Continue conditions but not for the Retain conditions. The RNP in the Continue conditions was evident in longer engagement of the Target, delayed engagement of the Interactor, and early engagement of the Distractor for names than for pronouns. The absence of a similar effect in the Retain conditions indicates that fronting the non-subject referent rapidly eliminated the RNP. The fact that the salience of grammatical subjects was sensitive to the fronting manipulation provides evidence for the interaction of information structure and grammatical structure constraints on referential processing.

An interesting finding was the difference between the Retain Pronoun and Continue Noun conditions in looks to the Distractor and the Unrelated object. In both these conditions the anaphor form is the less preferable given the salience of the referent. While looks to the Target and the Interactor during the second half of the time window were very similar in these two conditions, looks to the Distractor decreased and looks to the Unrelated object, which was not an possible referent, increased in the Retain Pronoun condition during that time window. It therefore appears that when a noun is used to refer to the more salient referent, other possible referents are considered. But when a pronoun is used to refer to a less salient entity, such referents are instead suppressed.

Overall, these results suggest that fronting can eliminate the salience enhancing effect of grammatical subjecthood. However, before concluding that the two factors have a comparable effect on referent salience, it is necessary to examine whether fronting is similar to subjecthood in that it can create an RNP for non-subject referents.

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Table 2.1 Sample Verbal Item in Four Conditions in Experiment 1

Reference	Discourse	
	Continue	Retain
Noun	1. The woman with the purse yelled at the doctor about smoking in the hospital. 2. In her opinion, she should not have done that. 3. The woman apologized to the doctor about the incident.	1. The woman with the purse yelled at the doctor about smoking in the hospital. 2. In his opinion, she should not have done that. 3. The woman apologized to the doctor about the incident.
Pronoun	1. The woman with the purse yelled at the doctor about smoking in the hospital. 2. In her opinion, she should not have done that. 3. She apologized to the doctor about the incident.	1. The woman with the purse yelled at the doctor about smoking in the hospital. 2. In his opinion, she should not have done that. 3. She apologized to the doctor about the incident.

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Table 2.2 Growth Curve Models Used for Fitting Proportion of Looks to a Given Item for Subject i at Time Point j[1]

[1] Base	$Y_{ij} = \beta_{0i} + \beta_{1i} * \text{Time}_{ij} + \beta_{2i} * \text{Time}^2_{ij} + \beta_{3i} * \text{Time}^3_{ij} + \beta_{4i} * \text{Time}^4_{ij} + \varepsilon_{ij}$ $\beta_{0i} = \gamma_{00} + \zeta_{0i}$ $\beta_{1i} = \gamma_{10} + \zeta_{1i}$ $\beta_{2i} = \gamma_{20} + \zeta_{2i}$ $\beta_{3i} = \gamma_{30} + \zeta_{3i}$ $\beta_{4i} = \gamma_{40} + \zeta_{4i}$
[2] Intercept	$Y_{ij} = \beta_{0i} + \beta_{1i} * \text{Time}_{ij} + \beta_{2i} * \text{Time}^2_{ij} + \beta_{3i} * \text{Time}^3_{ij} + \beta_{4i} * \text{Time}^4_{ij} + \varepsilon_{ij}$ $\beta_{0i} = \gamma_{00} + \gamma_{01} * \text{Discourse} * \text{Reference} + \zeta_{0i}$ $\beta_{1i} = \gamma_{10} + \zeta_{1i}$

[1] All the models we tested included in the first level fixed effects of intercept, linear time (Time) reflecting slope, and quadratic time (Time2) reflecting acceleration (rise & fall rate). The second level equations were used to estimate the effect of condition on the intercept (β0i) and on the time course at the different orders (β1i and β2i). For simplicity, the models presented in the table show one coefficient for each interaction although the models we fitted included individual terms for all the lower level interactions and main effects as well (i.e., each of the γX1 coefficients in the table is in fact a matrix product of a coefficient matrix and a variable selection matrix). Our models always included a random effect of participants on the intercept, slope, and acceleration (ζ0i, ζ1i , and ζ2i), thus allowing both the estimated baseline distance and linear and quadratic rates of change in distance to vary across individuals. Correlations between the random effects were modeled as well.

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	$\beta_{2i} = \gamma_{20} + \zeta_{2i}$ $\beta_{3i} = \gamma_{30} + \zeta_{3i}$ $\beta_{4i} = \gamma_{40} + \zeta_{4i}$
[3] Linear	$Y_{ij} = \beta_{0i} + \beta_{1i} * \text{Time}_{ij} + \beta_{2i} * \text{Time}^2_{ij} + \beta_{3i} * \text{Time}^3_{ij} + \beta_{4i} * \text{Time}^4_{ij} + \varepsilon_{ij}$ $\beta_{0i} = \gamma_{00} + \gamma_{01} * \text{Discourse} * \text{Reference} + \zeta_{0i}$ $\beta_{1i} = \gamma_{10} + \gamma_{11} * \text{Discourse} * \text{Reference} + \zeta_{1i}$ $\beta_{2i} = \gamma_{20} + \zeta_{2i}$ $\beta_{3i} = \gamma_{30} + \zeta_{3i}$ $\beta_{4i} = \gamma_{40} + \zeta_{4i}$
[4] Quadratic	$Y_{ij} = \beta_{0i} + \beta_{1i} * \text{Time}_{ij} + \beta_{2i} * \text{Time}^2_{ij} + \beta_{3i} * \text{Time}^3_{ij} + \beta_{4i} * \text{Time}^4_{ij} + \varepsilon_{ij}$ $\beta_{0i} = \gamma_{00} + \gamma_{01} * \text{Discourse} * \text{Reference} + \zeta_{0i}$ $\beta_{1i} = \gamma_{10} + \gamma_{11} * \text{Discourse} * \text{Reference} + \zeta_{1i}$ $\beta_{2i} = \gamma_{20} + \gamma_{21} * \text{Discourse} * \text{Reference} + \zeta_{2i}$ $\beta_{3i} = \gamma_{30} + \zeta_{3i}$ $\beta_{4i} = \gamma_{40} + \zeta_{4i}$

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[5] Cubic	$Y_{ij} = \beta_{0i} + \beta_{1i} * \text{Time}_{ij} + \beta_{2i} * \text{Time}^2_{ij} + \beta_{3i} * \text{Time}^3_{ij} + \beta_{4i} * \text{Time}^4_{ij} + \varepsilon_{ij}$ $\beta_{0i} = \gamma_{00} + \gamma_{01} * \text{Discourse} * \text{Reference} + \zeta_{0i}$ $\beta_{1i} = \gamma_{10} + \gamma_{11} * \text{Discourse} * \text{Reference} + \zeta_{1i}$ $\beta_{2i} = \gamma_{20} + \gamma_{21} * \text{Discourse} * \text{Reference} + \zeta_{2i}$ $\beta_{3i} = \gamma_{30} + \gamma_{31} * \text{Discourse} * \text{Reference} + \zeta_{3i}$ $\beta_{4i} = \gamma_{40} + \zeta_{4i}$
[6] Quartic	$Y_{ij} = \beta_{0i} + \beta_{1i} * \text{Time}_{ij} + \beta_{2i} * \text{Time}^2_{ij} + \beta_{3i} * \text{Time}^3_{ij} + \beta_{4i} * \text{Time}^4_{ij} + \varepsilon_{ij}$ $\beta_{0i} = \gamma_{00} + \gamma_{01} * \text{Discourse} * \text{Reference} + \zeta_{0i}$ $\beta_{1i} = \gamma_{10} + \gamma_{11} * \text{Discourse} * \text{Reference} + \zeta_{1i}$ $\beta_{2i} = \gamma_{20} + \gamma_{21} * \text{Discourse} * \text{Reference} + \zeta_{2i}$ $\beta_{3i} = \gamma_{30} + \gamma_{31} * \text{Discourse} * \text{Reference} + \zeta_{3i}$ $\beta_{4i} = \gamma_{40} + \gamma_{41} * \text{Discourse} * \text{Reference} + \zeta_{4i}$

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Table 2.3 The Chosen Model for Experiment 1 Target[2]

Effect	Estimate	Std. Error	Z	p
(Intercept)	0.53	0.11	4.68	0.00
Time	1.70	1.55	1.10	0.27
$Time^2$	1.52	1.27	1.20	0.23
$Time^3$	1.32	0.67	1.95	0.05
$Time^4$	0.59	0.23	2.59	0.01
Discourse	0.15	0.06	2.38	0.02
Reference	0.09	0.06	1.38	0.17
Discourse * Reference	-0.15	0.09	-1.68	0.09
Time * Discourse	2.46	0.85	2.91	0.00
Time * Reference	1.13	0.85	1.34	0.18
$Time^2$ * Discourse	2.65	0.61	4.36	0.00
$Time^2$ * Reference	0.65	0.61	1.07	0.29

[2] The predictors are orthogonalized time polynomials to the 4^{th} level, Discourse (1 = Continue, 0 = Retain), Reference (1 = Pronoun, 0 = Noun). Because our data set was large and included many data points, we used the normal distribution approximation for significance tests for the coefficients in the chosen model (Long, 2012). These are shown as the Z and p values for the different coefficients.

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$Time^3$ * Discourse	1.03	0.25	4.04	0.00
$Time^3$ * Reference	0.10	0.25	0.40	0.69
Time * Discourse * Reference	-2.74	1.20	-2.29	0.02
$Time^2$ * Discourse * Reference	-2.41	0.86	-2.81	0.01
$Time^3$ * Discourse * Reference	-0.83	0.36	-2.30	0.02

Table 2.4 Experiment 1 Target Models[3]

(a)

Model	**AICc**	**K**	**Δ**	**W**	**E**
cubic	-2030.86	33	0.00	0.43	1.00
simplest	-2030.86	33	0.00	0.86	1.00
quartic	-2028.59	36	2.27	1.00	3.11
quadratic	-2016.99	30	13.87	1.00	1026.43
slope	-2015.60	27	15.26	1.00	2058.17
intercept	-1761.47	24	269.39	1.00	3.145 x

[3] (a) Fit information for compared models. *AICc* – AIC corrected, *K* – degrees of freedom, *Δ* – change in *AICc*, *W* – relative weight of evidence for model among compared models, *E* – ratio of evidence for model in comparison to the most likely model. (b) Maximum likelihood model comparison. Each model is compared to the one immediately above it using Chi square test of log likelihoods.

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					10^{58}
base	-1635.86	21	395.00	1.00	5.927 x 10^{85}

(b)

Model	**df**	**AIC**	**logLik**	χ^2	**df**	**p**
base	21	-1635.9	838.97			
intercept	24	-1761.6	904.79	131.63	3	0.00
slope	27	-2015.7	1034.87	260.16	3	0.00
quadratic	30	-2017.2	1038.58	7.42	3	0.06
simplest	33	-2031.1	1048.53	19.90	3	0.00
cubic	33	-2031.1	1048.53	0.00	0	1.00
quartic	36	-2028.8	1050.42	3.77	3	0.29

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Table 2.5 The Chosen Model for Experiment 1 Interactor.[4]

Effect	Estimate	Std. Error	Z	p
(Intercept)	0.25	0.13	1.99	0.05
Time	-0.06	1.72	-0.04	0.97
$Time^2$	-0.25	1.39	-0.18	0.86
$Time^3$	-0.56	0.76	-0.74	0.46
$Time^4$	-0.21	0.24	-0.90	0.37
Discourse	-0.54	0.13	-4.03	0.00
Reference	0.33	0.13	2.47	0.01
Discourse * Reference	0.10	0.03	4.19	0.00
Time * Discourse	-7.06	1.85	-3.81	0.00
Time * Reference	4.95	1.85	2.67	0.01
$Time^2$ * Discourse	-6.22	1.49	-4.18	0.00
$Time^2$ * Reference	4.18	1.49	2.82	0.01

[4] The predictors are orthogonalized time polynomials to the 4^{th} level, Discourse (1 = Continue, 0 = Retain), Reference (1 = Pronoun, 0 = Noun). Because our data set was large and included many data points, we used the normal distribution approximation for significance tests for the coefficients in the chosen model (Long, 2012). These are shown as the Z and p values for the different coefficients.

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$Time^3$ * Discourse	-2.98	0.80	-3.73	0.00
$Time^3$ * Reference	2.59	0.80	3.25	0.00
$Time^4$ * Discourse	-0.76	0.25	-3.01	0.00
$Time^4$ * Reference	0.68	0.25	2.68	0.01
Time * Discourse * Reference	0.91	0.31	2.98	0.00
$Time^2$ * Discourse * Reference	1.01	0.19	5.36	0.00

Table 2.6 Experiment 1 Interactor Models[5]

(a)

Model	AICc	K	Δ	W	E
simplest	-5496.5	34	0.00	0.75	1.00
quartic	-5494.4	36	2.17	1.00	2.90
cubic	-5483.9	33	12.7	1.00	58
quadratic	-5461.8	30	34.8	1.00	3.5×10^7
slope	-5428.8	27	67.8	1.00	5.1×10^{14}

[5] (a) Fit information for compared models. (*AICc* – AIC corrected, *K* – degrees of freedom, *Δ* – change in *AICc*, *W* – relative weight of evidence for model among compared models, *E* – ratio of evidence for model in comparison to the most likely model). (b) Maximum likelihood model comparison. Each model is compared to the one immediately above it using Chi square test of log likelihoods.

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intercept	-5219.6	24	276.9	1.00	1.4×10^{60}
base	-5219.5	21	290.0	1.00	9.5×10^{62}

(b)

Model	**df**	**AIC**	**logLik**	χ^2	**df**	**p**
base	21	-5206.6	2624.3			
intercept	24	-5219.7	2633.8	19.09	3	0.00
slope	27	-5428.9	2741.5	215.2	3	0.00
quadratic	30	-5462.0	2761.0	39.0	3	0.00
cubic	33	-5484.0	2775.0	28.0	3	0.00
simplest	34	-5496.7	2782.4	14.7	1	0.00
quartic	36	-5494.6	2783.3	1.8	2	1.80

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Table 2.7 The Chosen Model for Experiment 1 Distractor[6]

Effect	Estimate	Std. Error	Z	p
(Intercept)	0.15	0.06	2.60	0.01
Time	0.31	0.80	0.39	0.69
$Time^2$	0.41	0.64	0.64	0.52
$Time^3$	0.34	0.33	1.03	0.31
$Time^4$	0.09	0.10	0.87	0.39
Discourse	0.01	0.00	4.16	0.00
Reference	0.03	0.00	9.15	0.00
$Time^2$ * Discourse	-0.47	0.05	-9.91	0.00
$Time^2$ * Reference	-0.39	0.05	-8.12	0.00
$Time^3$ * Discourse	-0.31	0.05	-5.91	0.00
$Time^3$ * Reference	-0.28	0.05	-5.39	0.00

[6] The predictors are orthogonalized time polynomials to the 4th level, Discourse (1 = Continue, 0 = Retain), Reference (1 = Pronoun, 0 = Noun). Because our data set was large and included many data points, we used the normal distribution approximation for significance tests for the coefficients in the chosen model (Long, 2012). These are shown as the Z and p values for the different coefficients.

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$Time^2$ * Discourse * Reference	0.61	0.07	9.10	0.00
$Time^3$ * Discourse * Reference	0.46	0.07	6.22	0.00

Table 2.8 Experiment 1 Distractor Models[7]

(a)

Model	AICc	K	Δ	W	E
simplest	-10371.5	25	0.0	0.6	1.00
cubic	-10370.1	29	1.3	0.9	2.01
quartic	-10366.7	32	4.8	0.95	4.43
quadratic	-10366.0	26	5.4	0.99	9908.68
slope	10362.0	23	9.4	1.0	2.81×10^{7}
intercept	10273.9	20	97.6	1.0	1.08×10^{23}
base	10159.7	17	211.8	1.0	4.91×10^{45}

[7] (a) Fit information for compared models. (*AICc* – AIC corrected, *K* – degrees of freedom, *Δ* – change in *AICc*, *W* – relative weight of evidence for model among compared models, *E* – ratio of evidence for model in comparison to the most likely model). (b) Maximum likelihood model comparison. Each model is compared to the one immediately above it using Chi square test of log likelihoods.

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(b)

Model	df	AIC	logLik	χ^2	df	p
base	17	-10160	5096.9			
intercept	20	-10274	5157.0	120.2	3	0.00
slope	23	-10362	5204.1	77	3	0.00
simplest	25	-10372	5210.8	4.99	2	0.03
quadratic	26	-10176	5209.1	21.93	1	0.00
cubic	29	-10158	5214.2	21.46	3	0.00
quartic	32	-10132	5215.4	2.63	3	0.27

Table 2.9 The Chosen Model for Experiment 1 Unrelated Object[8]

Effect	Estimate	Std. Error	Z	p
(Intercept)	-0.07	0.08	-0.90	0.37
Time	-2.45	1.04	-2.36	0.02
$Time^2$	-2.19	0.83	-2.65	0.01

[8] The predictors are orthogonalized time polynomials to the 4th level, Discourse (1 = Continue, 0 = Retain), Reference (1 = Pronoun, 0 = Noun). Because our data set was large and included many data points, we used the normal distribution approximation for significance tests for the coefficients in the chosen model (Long, 2012). These are shown as the Z and p values for the different coefficients.

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$Time^3$	-1.35	0.45	-2.98	0.00
$Time^4$	-0.49	0.14	-3.47	0.00
Discourse	0.17	0.09	2.03	0.04
Reference	-0.07	0.01	-6.44	0.00
Discourse * Reference	0.02	0.01	2.62	0.01
Time * Discourse	2.30	1.19	1.94	0.05
Time * Reference	-0.64	0.14	-4.61	0.00
$Time^2$ * Discourse	2.06	0.95	2.16	0.03
$Time^2$ * Reference	-0.11	0.08	-1.43	0.15
$Time^3$ * Discourse	1.20	0.51	2.34	0.02
$Time^4$ * Discourse	0.36	0.16	2.24	0.03
$Time^4$ * Reference	0.10	0.03	3.18	0.00
Time * Discourse * Reference	0.47	0.07	6.33	0.00

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Table 2.10 Experiment 1 Unrelated Object Models[9]

(a)

Model	AICc	K	Δ	W	E
simplest	-15328.51	32	0.00	0.81	1.00
quartic	-15325.38	36	3.13	0.98	4.80
cubic	-15319.96	33	8.55	0.99	72.00
quadratic	-15316.90	30	11.6	0.99	330.00
slope	15313.52	27	14.9	1	1800.00
intercept	-15256.65	24	71.9	1	4.02×10^{15}
base	-15024.81	21	303.7	1	8.9×10^{65}

(b)

Model	df	AIC	logLik	χ^2	df	p
base	21	-15025	7533.4			
intercept	24	-15257	7652.4	237.8	3	0.00
slope	27	-15314	7683.8	62.9	3	0.00

[9] (a) Fit information for compared models. (*AICc* – AIC corrected, *K* – degrees of freedom, *Δ* – change in *AICc*, *W* – relative weight of evidence for model among compared models, *E* – ratio of evidence for model in comparison to the most likely model). (b) Maximum likelihood model comparison. Each model is compared to the one immediately above it using Chi square test of log likelihoods.

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quadratic	30	-15317	7688.5	9.4	3	0.02
simplest	32	-15329	7696.4	15.6	2	0.00
cubic	23	-15320	7693.1	0.0	1	1.00
quartic	36	-15326	7698.8	11.4	3	0.00

Interactor

Target

Distractor

Unrelated object

Figure 2.1 Sample visual display.

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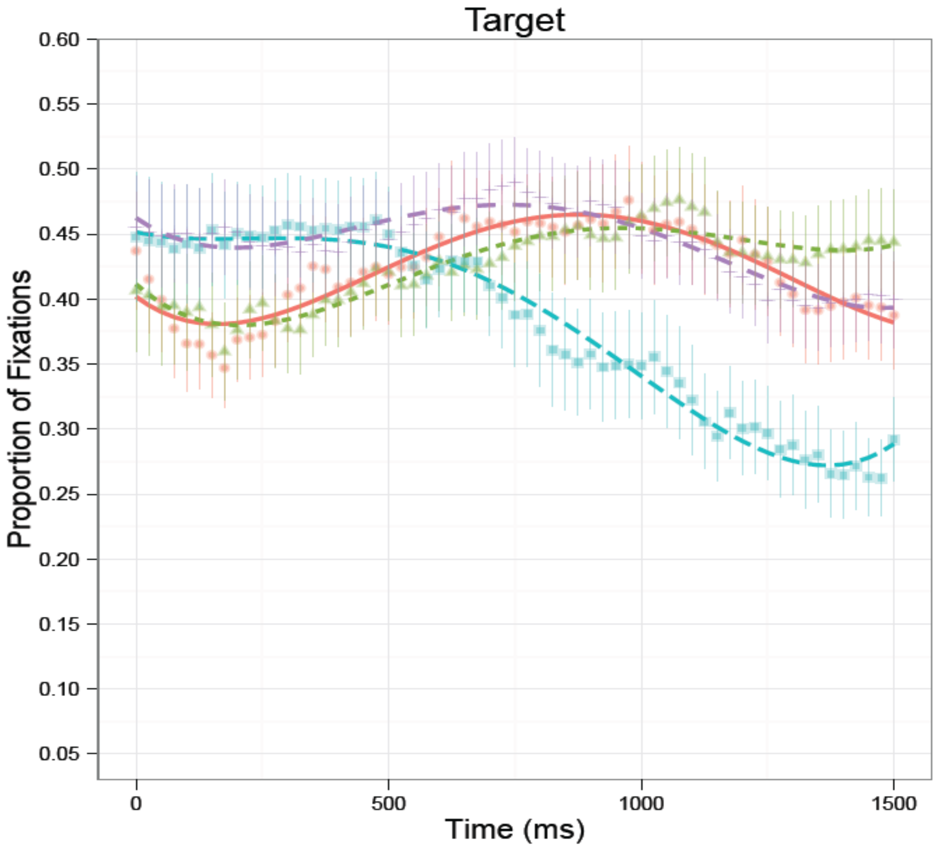

Figure 2.2 The time course of activation for the Target in the Retain Noun (green), Retain Pronoun (red), Continue Noun (purple) and Continue Pronoun (blue) conditions in Experiment 1.

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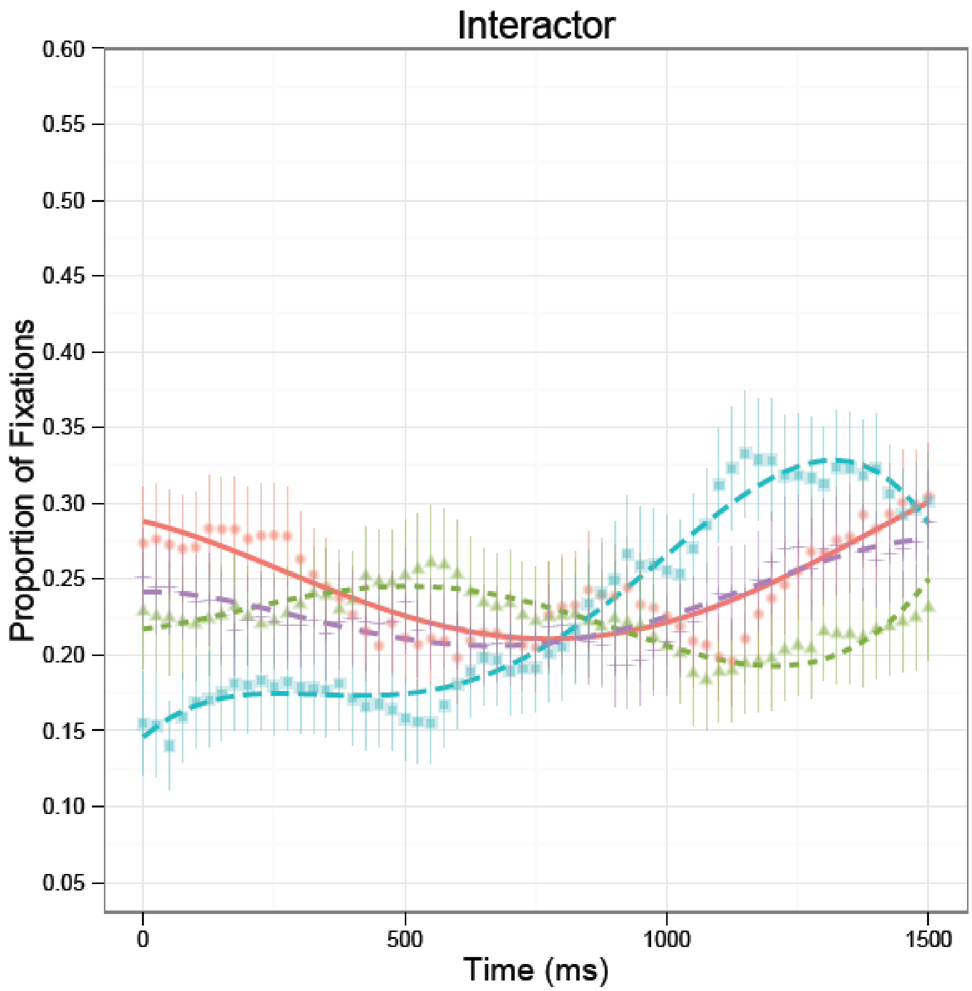

Figure 2.3 The time course of activation for the Interactor in the Retain Noun (green), Retain Pronoun (red), Continue Noun (purple) and Continue Pronoun (blue) conditions in Experiment 1.

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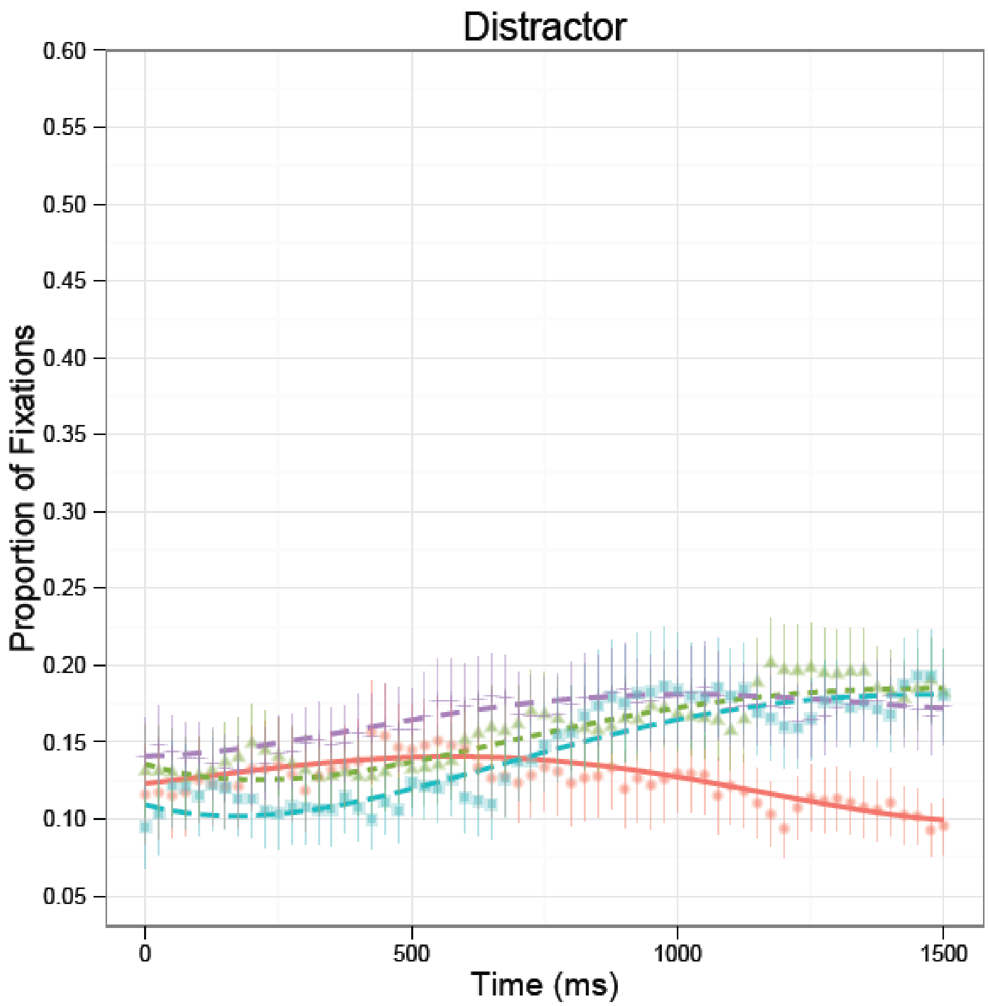

Figure 2.4 The time course of activation for the Distractor in Retain Noun (green), Retain Pronoun (red), Continue Noun (purple) and Continue Pronoun (blue) conditions in Experiment 1.

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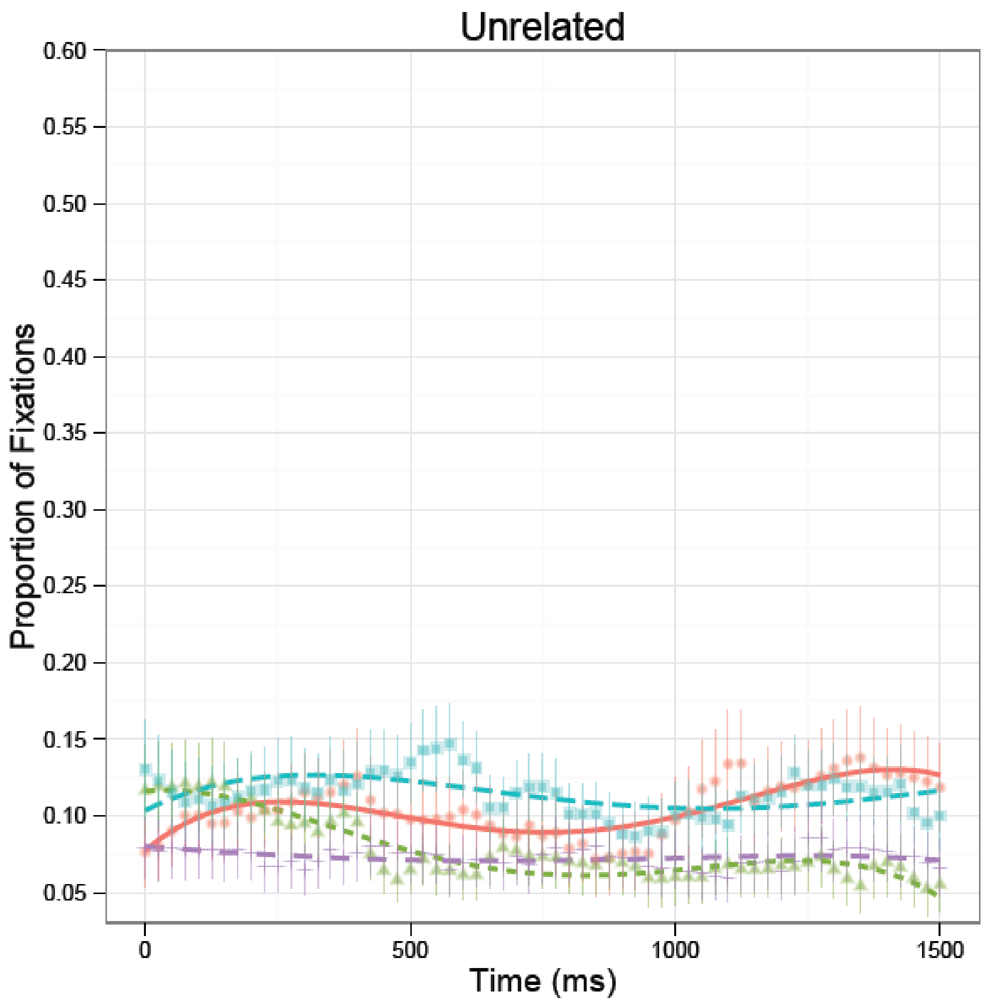

Figure 2.5 The time course of activation for the Unrelated object in Retain Noun (green), Retain Pronoun (red), Continue Noun (purple) and Continue Pronoun (blue) conditions in Experiment 1.

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CHAPTER 3 – EXPERIMENT 2

Experiment 1 showed that fronting, an information structure salience enhancer, affects the processing of repeated anaphors and pronouns, and it is powerful enough to eliminate the RNP elicited by subjecthood. Before concluding that information structure constraints have a comparable effect on salience to grammatical subjecthood, it will be necessary to demonstrate that information structure can increase salience as much as grammatical subjecthood. Experiment 2 therefore asked whether fronting a non-subject antecedent would create an effect similar to the effect elicited by subjecthood. The specific goal of Experiment 2 was to determine whether fronting is powerful enough salience enhancer to elicit an RNP-like effect. To pursue this goal, we used a similar methodology to Experiment 1 with a few modifications of the verbal stimuli. We modified the syntactic prominence of the referents so that the Interactor rather than the Target was made grammatically salient, and then contrasted eye-movements to the different objects following noun and pronoun references to fronted and non-fronted Targets. Because in this experiment the Target was not grammatically salient, referring to it in the fronted phrase in Sentence 2 constituted the Smooth Shift condition as it facilitated processing Sentence 3. Referring to the Interactor in the fronted phrase constituted the Abrupt Shift condition. The experiment aimed to ascertain whether fronting the Target in the Smooth Shift condition can elicit the RNP. If fronting has an equivalent effect to subjecthood on salience, then the RNP should occur in the Smooth

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Shift conditions but not in the Abrupt Shift conditions. Following the previous experiment we expect that effect to be reflected in a quick disengagement of the Target and a quick engagement of the Interactor in the Smooth Shift pronoun condition relative to the other conditions. Observing the RNP in this experiment would indicate that an information structure constraint is similar to the grammatical subjecthood in terms of effect on salience. Failure to detect the RNP would indicate that fronting is either a weaker constraint on salience then subjecthood, or that fronting and subjecthood differ in their impact on salience.

3.1 METHODS

Participants

Fifty-five participants attending Psychology classes in USC served as subjects. They were all native speakers of American English and participated in the study for extra credit.

Material, procedure and data analysis

The set of 24 experimental discourses and 24 fillers from the previous experiment was modified. Table 10 shows a verbal item in all conditions. Sentence 1 introduced the Interactor in the subject position and the Target - in the object position. Sentence 2 started with a adverbial fronted phrase “In his/her opinion” with a pronominal reference to either the Interactor (the Abrupt Shift conditions) or the Target (the Smooth Shift conditions). Sentence 3 mentioned the Target in the subject position using either a definite NP (the Noun conditions) or pronoun (the Pronoun conditions) and the noun Interactor in the object position. Visual displays depicted the Interactor, Target, Distractor similar to

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Target except for one distinctive feature (the purse), and Unrelated item. Sample visual display is presented in Figure 1. All aspects of procedure and data analysis were the same as in Experiment 1.

3.2 RESULTS

The data from nineteen participants were discarded due to calibration and equipment errors. Eye position data from the remaining thirty-six participants were transformed into fixations using the ASL Results software following the procedure recommended by Lambert, Monty and Hall (1974). As in Experiment 1, GCA examined proportions of fixations to the Target, Interactor, Distractor and the Unrelated object in the 1500 ms time window following the offset of the Target in Sentence 3.

Fixations to the Target

The results of the model comparisons are shown in Tables 11 and 12. The best fitting model is shown in Figure 6**.** The best fitting model included an interaction between Discourse and Reference on the quadratic and cubic time terms. As is shown in both tables and figure, this effect was driven by the quickest and most accelerated disengagement of the Target in the Smooth Shift Pronoun condition (consistent with the results of Experiment 1), as well as by the quickest and most accelerated increase in looks to the Target in the Abrupt Shift Pronoun condition.

Fixations to the Interactor

The results of the model comparisons are shown in Tables 14 and 15. The best fitting model is shown in Figure 8. The best fitting model included an interaction between Discourse and Reference on the cubic term. In the Smooth Shift conditions looks to the

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Interactor were very similar following pronouns and nouns. In the Abrupt Shift conditions looks to the Interactor declined more quickly at the beginning of the time window and took longer to increase at the end of the time window following Pronouns than Nouns.

The patterns of fixations to the Target and the Interactor are not consistent with an RNP in the Smooth Shift conditions. Analysis of fixations to the Target suggested that participants quickly processed the Target in the Smooth Shift Pronoun condition, consistent with the RNP observed in Experiment 1.The analysis of fixations to the Interactor showed that participants did not look at the Interactor as they were disengaging the Target. This is different than the results of Experiment 1. The following analyses examine whether the decrease in looks to the Target was linked to an increase in looks to one of the unmentioned objects.

Fixations to the Distractor

The results of the model comparisons are shown in Tables 15 and 16, and the best fitting model is shown in Figure 8. The best fitting model included an interaction between Discourse and Reference on the linear, quadratic, and cubic terms. This interaction was driven by the steepest engagement of the Distractor in the Smooth Shift Pronoun condition and the sustained engagement of the Distractor in the Abrupt Shift Noun condition throughout most of the time window.

Fixations to the Unrelated Object

Our next GCA contrasted the proportion of fixations to the Unrelated object in the four conditions in the 1500 ms time window following the offset of the Target in Sentence 3. The results of model comparisons are shown in Tables 17 and 18, and the

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best fitting model is shown in Figure 9. The best fitting model included an interaction between Discourse and Reference on the linear, quadratic and cubic terms. Although the overall low number of fixations to the Unrelated object preclude strong conclusions from this analysis, the effects detected appear to mostly reflect sharp decline in looks to the Unrelated objects in the Abrupt Shift Noun condition.

3.3 DISCUSSION

The results of Experiment 2 showed that the fronting of the non- subject Target in the Smooth Shift conditions elicited an effect that is partially similar to the RNP. The quicker rate of disengaging the Target for pronouns than for names in the Smooth Shift conditions suggests that the pronoun references to the Target are easier to process. There were no similar differences in the Abrupt Shift conditions. These aspects of our findings are consistent with the RNP and support the idea that fronting, an information structure constraint, is a powerful enough salience enhancer to elicit the RNP effect for a non-subject entity.

However, unlike in Experiment 1, a quicker engagement of the Interactor did not accompany the quick disengagement of the Target. Instead, the disengagement of the Target in the Smooth Shift Pronoun condition, was accompanied by an engagement of the Distractor. Thus, in contrast to the RNP observed in Experiment 1, in which a pronoun reference to the salient entity facilitated the processing of both that pronoun and the reference following the pronoun, in this experiment, the pronoun reference to the salient entity facilitated only the processing of that pronoun. In the present experiment, rather than facilitating the processing of the reference following the pronoun, fronting the

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Target resulted in the consideration of alternative referents for the pronoun. This suggests that the later effects of the pronoun advantage created by fronting a non-subject referent are not the same as the pronoun advantage (RNP) elicited by grammatical subjecthood in Experiment 1. The fact that fronting of the Target can create the initial but not lasting pronoun advantage suggests that fronting is a strong salience enhancer, but its effect on salience is not identical to the effect of grammatical subjecthood.

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Table 3.1 Sample Verbal Item in Four Conditions in Experiment 2

Reference	Discourse	
	Retain	Shift
Noun	1. The doctor yelled at the woman with the purse about smoking in the hospital. 2. In her opinion, he should not have done that. 3. The woman apologized to the doctor about the incident anyway.	1. The doctor yelled at the woman with the purse about smoking in the hospital. 2. In his opinion, she should not have done that. 3. The woman apologized to the doctor about the incident.
Pronoun	1. The doctor yelled at the woman with the purse about smoking in the hospital. 2. In her opinion, he should not have done that. 3. She apologized to the doctor about the incident anyway.	1. The doctor yelled at the woman with the purse about smoking in the hospital. 2. In his opinion, she should not have done that. 3. She apologized to the doctor about the incident.

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Table 3.2 The Chosen Model for Experiment 2 Target[10]

Effect	Estimate	Std. Error	Z	p
(Intercept)	0.62	0.09	7.17	0.00
Time	2.33	1.11	2.10	0.04
$Time^2$	1.63	0.91	1.79	0.07
$Time^3$	1.54	0.53	2.89	0.00
$Time^4$	0.70	0.17	4.01	0.00
Time * Discourse	-0.22	0.07	-3.03	0.00
Time * Reference	0.39	0.07	5.28	0.00
$Time^2$ * Discourse	0.71	0.12	6.02	0.00
$Time^2$ * Reference	0.29	0.12	2.51	0.01

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[10] The predictors are orthogonalized time polynomials to the 4^{th} level, Discourse (1 = Abrupt Shift, 0 = Smooth Shift), Reference (1 = Noun, 0 = Pronoun). Because our data set was large and included many data points, we used the normal distribution approximation for significance tests for the coefficients in the chosen model (Long, 2012). These are shown as the Z and p values for the different coefficients.

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$Time^3$ * Discourse	0.20	0.14	1.43	0.15
$Time^3$ * Reference	-0.07	0.14	-0.48	0.63
$Time^4$ * Discourse	-0.10	0.10	-1.06	0.29
$Time^4$ * Reference	-0.10	0.10	-0.99	0.32
Time * Discourse * Reference	-0.88	0.10	-8.42	0.00
$Time^2$ * Discourse * Reference	-1.37	0.17	-8.23	0.00
$Time^3$ * Discourse * Reference	-0.85	0.19	-4.40	0.00
$Time^4$ * Discourse * Reference	-0.20	0.14	-1.44	0.15

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Table 3.3 Experiment 2 Target Models[11]

(a)

Model	AICc	K	Δ	W	E
simplest	-4785.58	33	0.00	0.48	1.00e+00
cubic	-4785.42	33	0.16	0.93	1.08e+00
quartic	-4780.88	36	4.70	0.98	1.05e+01
quadratic	-4779.58	30	6.00	1.00	2.00e+01
slope	-4763.24	27	22.34	1.00	7.10e+04
intercept	-4533.77	24	251.81	1.00	4.79e+54
base	-4422.74	21	362.85	1.00	6.18e+78

[11] (a) Fit information for compared models. (*AICc* – AIC corrected, *K* – degrees of freedom, *Δ* – change in *AICc*, *W* – relative weight of evidence for model among compared models, *E* – ratio of evidence for model in comparison to the most likely model). (b) Maximum likelihood model comparison. Each model is compared to the one immediately above it using Chi square test of log likelihoods.

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(b)

Model	df	AIC	logLik	χ^2	df	p
base	21	-4422.8	2232.4			
intercept	24	-4533.9	2290.9	117.06	3	< 2.2e-16
slope	27	-4763.4	2408.7	235.50	3	< 2.2e-16
quadratic	30	-4779.7	2419.9	22.37	3	5.457e-05
simplest	33	-4785.6	2425.9	12.03	3	0.008
cubic	33	-4785.6	2425.8	0	0	1.00
quartic	36	-4781.1	2426.6	1.50	3	0.682529

Table 3.4 The Chosen Model for Experiment 2 Interactor[12]

Effect	Estimate	Std. Error	Z	p
(Intercept)	0.25	0.07	3.61	0.00
Time	0.75	0.88	0.86	0.39
$Time^2$	0.71	0.70	1.01	0.31

[12] The predictors are orthogonalized time polynomials to the 4th level, Discourse (1 = Abrupt Shift, 0 = Smooth Shift), Reference (1 = Noun, 0 = Pronoun). Because our data set was large and included many data points, we used the normal distribution approximation for significance tests for the coefficients in the chosen model (Long, 2012). These are shown as the Z and p values for the different coefficients.

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$Time^3$	-0.10	0.39	-0.26	0.80
$Time^4$	-0.17	0.12	-1.41	0.16
Discourse	-0.07	0.04	-1.74	0.08
Reference	-0.14	0.04	-3.29	0.00
Discourse * Reference	0.12	0.06	1.96	0.05
Time * Discourse	-0.89	0.55	-1.62	0.11
Time * Reference	-1.51	0.55	-2.76	0.01
$Time^2$ * Discourse	-0.89	0.39	-2.26	0.02
$Time^2$ * Reference	-1.55	0.39	-3.94	0.00
$Time^3$ * Discourse	-0.29	0.16	-1.78	0.08
$Time^3$ * Reference	-0.56	0.16	-3.43	0.00
Time * Discourse * Reference	1.33	0.78	1.71	0.09
$Time^2$ * Discourse * Reference	1.42	0.56	2.56	0.01
$Time^3$ * Discourse * Reference	0.58	0.23	2.49	0.01

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Table 3.5 Experiment 2 Interactor models[13]

(a)

Model	AICc	K	Δ	W	E
quartic	-8261.89	36	0.00	0.62	1.00e+00
Cubic	-8260.89	33	1.00	0.38	1.65e+00
Quadratic	-8233.80	30	28.09	0.00	1.26e+06
Slope	-8214.33	27	47.56	0.00	2.13e+10
Intercept	-8029.86	25	232.03	0.00	2.42e+50
base	-8020.11	21	241.77	0.00	3.16e+52

(b)

Model	df	AIC	logLik	χ^2	df	p
base	21	-8020.2	4031.1	15.77		

[13] (a) Fit information for compared models. (*AICc* – AIC corrected, *K* – degrees of freedom, *Δ* – change in *AICc*, *W* – relative weight of evidence for model among compared models, *E* – ratio of evidence for model in comparison to the most likely model). (b) Maximum likelihood model comparison. Each model is compared to the one immediately above it using Chi square test of log likelihoods.

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intercept	24	-8030.0	4039.0	190.49	3	0.001
slope	27	-8214.5	4134.2	25.50	3	< 2.2e-16
quadratic	30	-8234.0	4147.0	33.12	3	1.213e-05
cubic	33	-8261.1	4163.5	33.12	3	3.032e-07
quartic	36	-8262.1	4167.1	7.04	3	0.07

Table 3.6 The Chosen Model for Experiment 2 Distractor[14]

Effect	Estimate	Std. Error	Z	p
(Intercept)	0.11	0.08	1.39	0.16
Time	-0.30	1.07	-0.28	0.78
$Time^2$	-0.36	0.84	-0.43	0.67
$Time^3$	-0.32	0.44	-0.73	0.47
$Time^4$	-0.24	0.14	-1.71	0.09
Discourse	-0.11	0.04	-2.65	0.01

[14] The predictors are orthogonalized time polynomials to the 4^{th} level, Discourse (1 = Abrupt Shift, 0 = Smooth Shift), Reference (1 = Noun, 0 = Pronoun). Because our data set was large and included many data points, we used the normal distribution approximation for significance tests for the coefficients in the chosen model (Long, 2012). These are shown as the Z and p values for the different coefficients.

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Reference	0.05	0.11	0.48	0.63
Discourse * Reference	0.17	0.06	2.81	0.00
Time * Discourse	-1.81	0.55	-3.26	0.00
Time * Reference	0.18	1.46	0.12	0.90
$Time^2$ * Discourse	-1.62	0.40	-4.08	0.00
$Time^2$ * Reference	0.47	1.17	0.41	0.68
$Time^3$ * Discourse	-0.67	0.17	-4.02	0.00
$Time^3$ * Reference	0.67	0.62	1.08	0.28
$Time^4$ * Reference	0.43	0.19	2.23	0.03
Time * Discourse * Reference	3.10	0.78	3.95	0.00
$Time^2$ * Discourse * Reference	2.36	0.56	4.21	0.00
$Time^3$ * Discourse * Reference	0.86	0.23	3.64	0.00

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Table 3.7 Experiment 2 Distractor Models[15]

(a)

Model	AICc	K	Δ	W	E
cubic	-13481.72	29	0.00	0.47	1.00e+00
quartic	-13480.92	32	0.80	0.78	1.50e+00
simplest	-13479.83	30	1.89	0.97	2.57e+00
quadratic	-13476.18	26	5.54	0.99	1.59e+01
slope	-13467.36	23	14.37	1.00	1.31e+03
intercept	-13362.36	20	119.36	1.00	8.29e+25
base	-13163.64	17	318.08	1.00	1.78e+69

(b)

Model	df	AIC	logLik	χ^2	df	p
base	17	-13164	6598.8			
intercept	20	-13362	6701.2	204.74	3	< 2.2e-16

[15] (a) Fit information for compared models. (*AICc* – AIC corrected, *K* – degrees of freedom, *Δ* – change in *AICc*, *W* – relative weight of evidence for model among compared models, *E* – ratio of evidence for model in comparison to the most likely model). (b) Maximum likelihood model comparison. Each model is compared to the one immediately above it using Chi square test of log likelihoods.

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slope	23	-13468	6756.7	111.02	3	< 2.2e-16
simplest	25	-13476	6764.2	14.84	3	0.002
quadratic	26	-13482	6769.9	11.57	3	0.01
cubic	29	-13480	6770.0	0.11	1	0.73
quartic	32	-13481	6772.6	5.10	2	0.08

Table 3.8 The Chosen Model for Experiment 2 Unrelated Object[16]

Effect	Estimate	Std. Error	Z	p
(Intercept)	-0.02	0.05	-0.42	0.67
Time	-1.27	0.76	-1.67	0.09
Time^2	-0.99	0.59	-1.66	0.10
Time^3	-0.65	0.33	-1.99	0.05
Time^4	-0.16	0.09	-1.72	0.08
Discourse	0.06	0.03	2.16	0.03

[16] The predictors are orthogonalized time polynomials to the 4th level, Discourse (1 = Abrupt Shift, 0 = Smooth Shift), Reference (1 = Noun, 0 = Pronoun). Because our data set was large and included many data points, we used the normal distribution approximation for significance tests for the coefficients in the chosen model (Long, 2012). These are shown as the Z and p values for the different coefficients.

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Reference	0.09	0.03	3.32	0.00
Discourse * Reference	-0.17	0.04	-4.35	0.00
Time * Discourse	0.68	0.37	1.82	0.07
Time * Reference	1.34	0.37	3.59	0.00
$Time^2$ * Discourse	0.40	0.27	1.50	0.13
$Time^2$ * Reference	1.08	0.27	4.04	0.00
$Time^3$ * Discourse	0.29	0.11	2.56	0.01
$Time^3$ * Reference	0.47	0.11	4.16	0.00
Time * Discourse * Reference	-2.33	0.53	-4.41	0.00
$Time^2$ * Discourse * Reference	-1.73	0.38	-4.58	0.00
$Time^3$ * Discourse * Reference	-0.80	0.16	-5.08	0.00

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Table 3.9 Experiment 2 Unrelated Object Models[17]

(a)

Model	AICc	K	Δ	W	E
Quadratic	-18009.73	30	0.00	0.79	1.00e+00
Cubic	-18005.59	33	4.14	0.89	7.92e+00
Quartic	-18004.74	36	5.00	0.95	1.21e+01
Slope	-18003.96	27	5.77	0.99	1.80e+01
Intercept	-17985.99	24	23.74	1.0	1.43e+05
base	-17705.93	21	303.80	1.0	9.32e+65

(b)

Model	df	AIC	logLik	χ^2	df	p
base	21	-17706	8874.0			
intercept	24	-17986	9017.1	286.08	3	<2.2e-16
slope	27	-18004	9029.0	24.10	3	2.51e-0.5

[17] (a) Fit information for compared models. (*AICc* – AIC corrected, *K* – degrees of freedom, *Δ* – change in *AICc*, *W* – relative weight of evidence for model among compared models, *E* – ratio of evidence for model in comparison to the most likely model). (b) Maximum likelihood model comparison. Each model is compared to the one immediately above it using Chi square test of log likelihoods.

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quadratic	30	-18010	9034.9	11.80	3	0.01
cubic	33	-18006	9035.9	1.90	3	0.60
quartic	36	-18005	9038.5	5.18	3	0.16

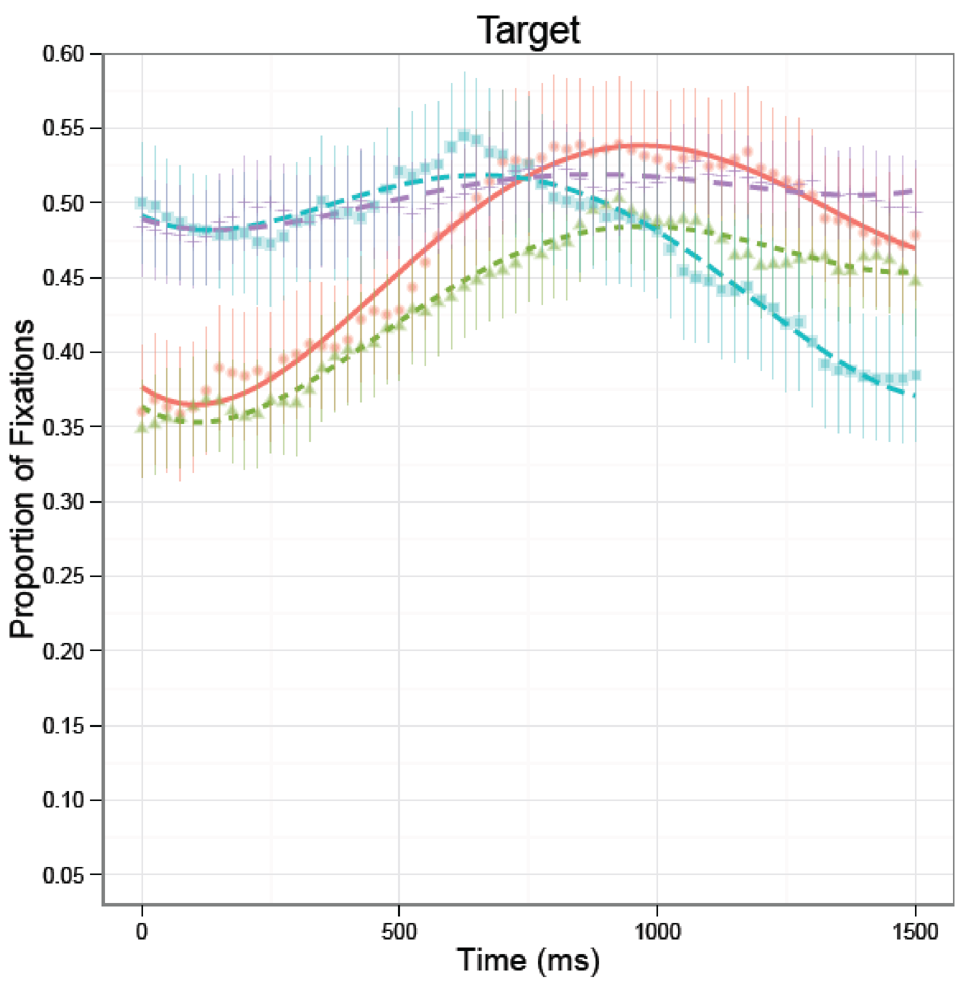

Figure 3.1 The time course of activation for the Target in Smooth Shift Noun (purple), Smooth Shift Pronoun (blue), Abrupt Shift Noun (green) and Abrupt Shift Pronoun (red) conditions in Experiment 2**.**

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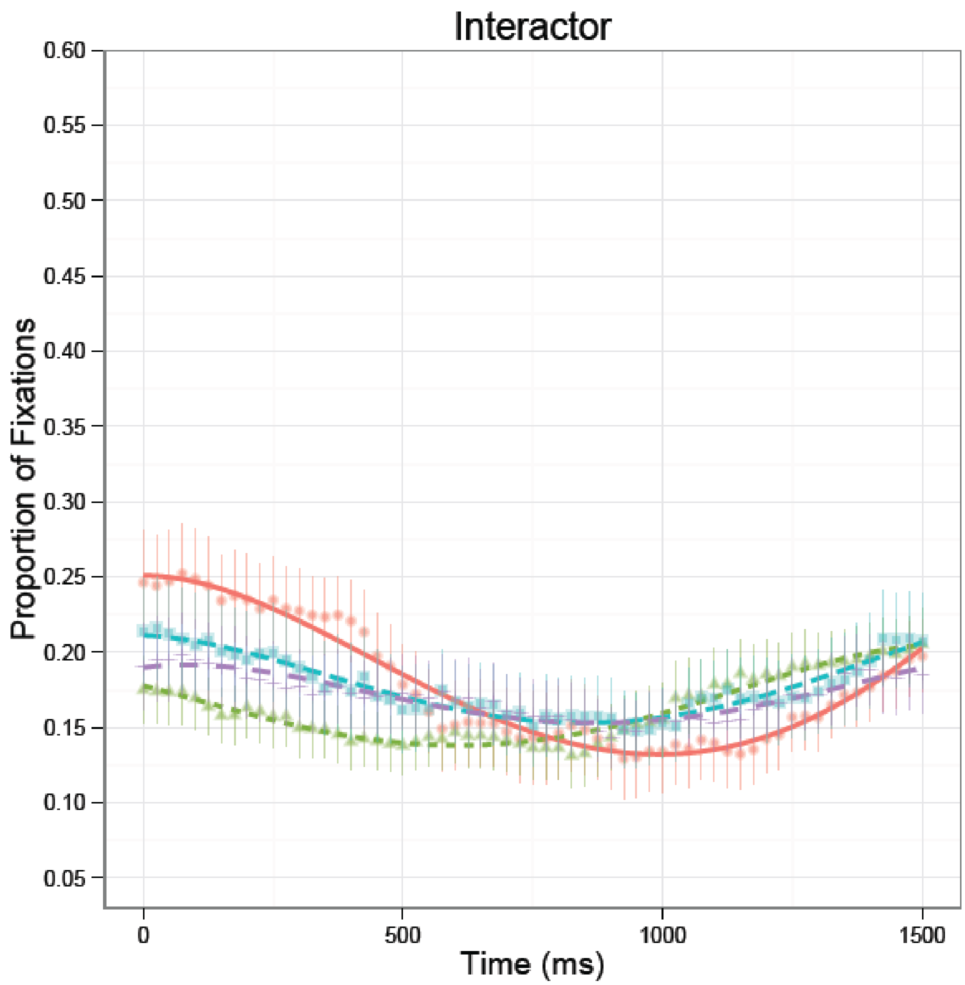

Figure 3.2 The time course of activation for the Interactor in Smooth Shift Noun (purple), Smooth Shift Pronoun (blue), Abrupt Shift Noun (green) and Abrupt Shift Pronoun (red) conditions in Experiment 2.

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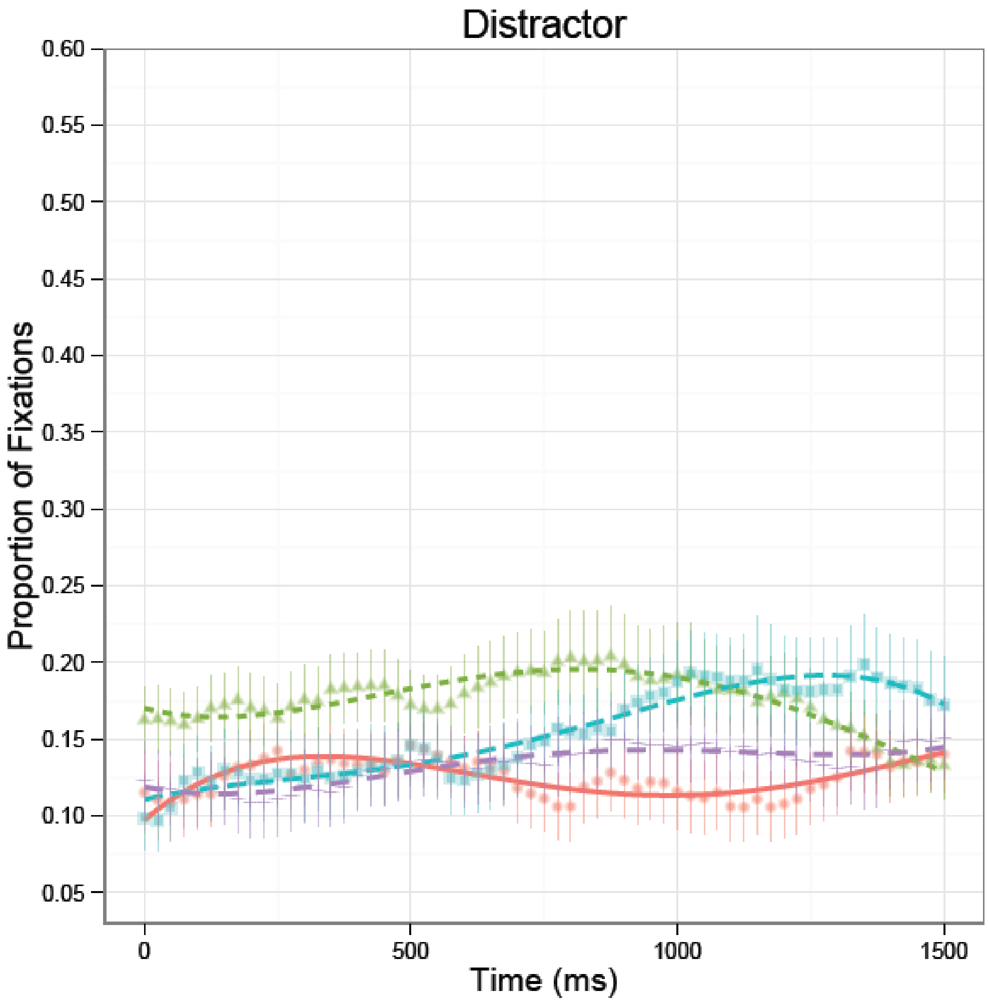

Figure 3.3 The time course of activation for the Distractor in Smooth Shift Noun (purple), Smooth Shift Pronoun (blue), Abrupt Shift Noun (green) and Abrupt Shift Pronoun (red) conditions in Experiment 2.

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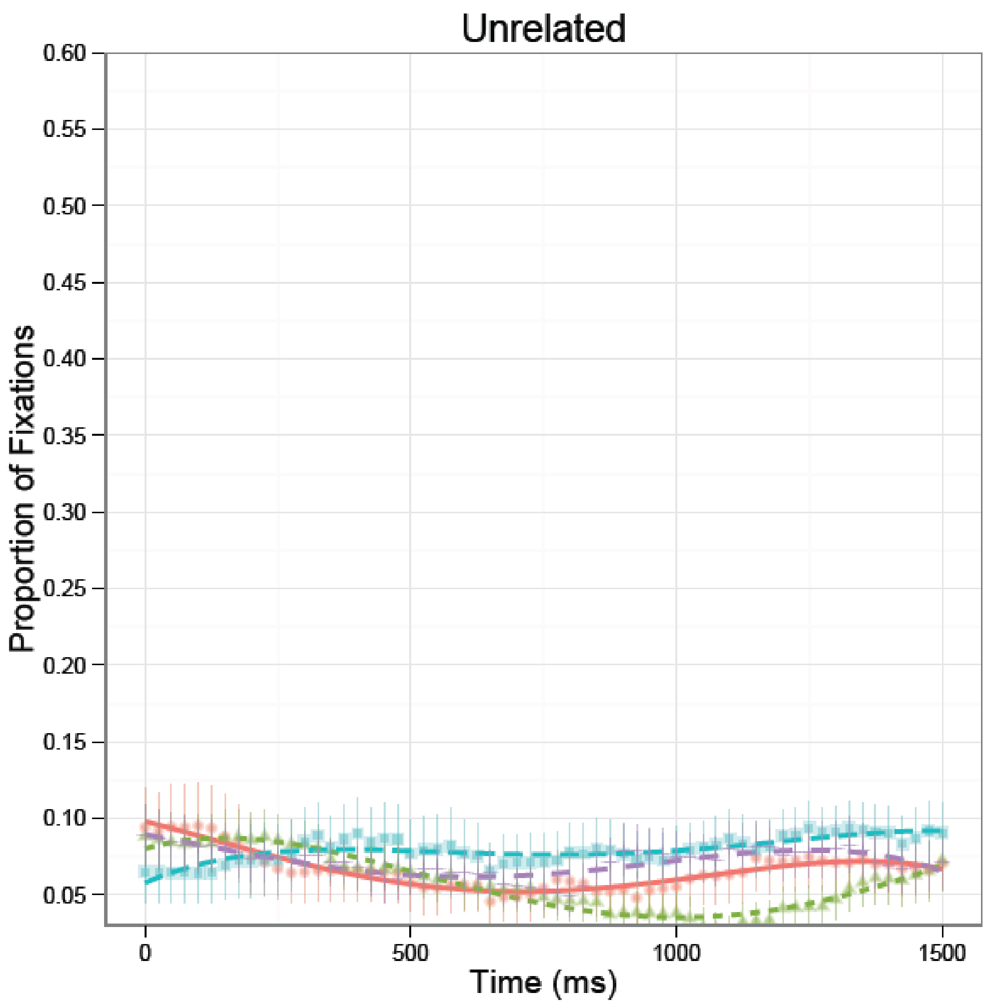

Figure 3.4 The time course of activation for the Unrelated object in Smooth Shift Noun (purple), Smooth Shift Pronoun (blue), Abrupt Shift Noun (green) and Abrupt Shift Pronoun (red) conditions in Experiment 2.

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CHAPTER 4 – GENERAL DISCUSSION

Taken together, the results of the two experiments provide important information concerning the interaction of information structure and grammatical structure constraints on reference processing. The results demonstrate that fronting, an information structure constraint, increases referent salience and affects the processing of repeated anaphors and pronouns with both grammatical subject antecedents and non-subject antecedents. More specifically, our experiments provide evidence that fronting of a non-subject entity can eliminate the RNP for the grammatical subject, and can elicit an effect similar but not identical to the RNP for a fronted non-subject entity.

Experiment 1 found that the RNP elicited by antecedents` grammatical subjecthood was eliminated when a non-subject entity was mentioned in an adverbial fronted phrase preceding the antecedent. When the fronted phrase referred to the subject entity, the RNP was reflected in the quicker processing of an initial pronoun reference and the reference following it compared to the processing of an initial repeated name and the reference following it. These differences were not observed when the fronted phrase in the previous sentence mentioned a referent different than the subject. The absence of the RNP for the grammatical subject in these conditions indicates that it was no longer the most likely candidate for the subsequent anaphoric reference. This indicates that fronting made the fronted entity salient enough to compete with the subject entity for the status of the antecedent of a pronoun. This finding supports Cowles (2007) claim that

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information structure constraints can override a strong grammatical structure constraint such as subjecthood.

Experiment 2 found that fronting a referent can increase its salience and initially create an RNP-like effect in that processing a pronoun reference to the fronted entity is quicker than processing a repeated name reference. However, despite this initial similarity to the RNP found in Experiment 1, the processing of the second reference differed in the two experiments. In Experiment 2, the processing the second reference was not different following pronoun and noun references to the fronted entity. Fixation patterns to the other pictures in the two experiments suggest that the RNP for references to subject antecedents is associated with the consideration of other possible referents for the repeated noun as it is processed. In contrast, the RNP for references to fronted antecedents is associated with the consideration of other referents for the pronoun later in the sentence during the processing of the second reference. Although the finding of the early RNP in this experiment is in line with the results of Gordon's et al. (1993), who found that fronting a non-subject referent was sufficient to make that referent the most salient entity in the utterance, the results of our experiments show that subjecthood and fronting have a similar but not identical effect on salience. This likely reflects the difference between Gordon's et al. self-paced reading methodology, which can only reveal processing difficulty, and our visual world methodology, which revealed different sources for the processing difficulty in the two experiments.

Another important difference between the present study and Gordon et al. (1993) is that here we attribute the effect of fronting to its information status role, whereas Gordon et al. attributed this effect to the influence of order of mention. Although our

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results do not speak directly to this issue, work by Bezuidenhout et al. (2009) shows that the effect of fronting on reference likely reflects information structure constraints. Bezuidenhout et al. argue that the effect of fronting on salience depends on whether the information in the fronted phrase is subordinate to the information conveyed by the main clause. In the stimuli we used, the information in the fronted phrases contributed substantially to the meaning of the main clause and was not merely subordinate to it. This, according to Bezuidenhout et al., and not the order of mention is the reason for the effects of fronting on salience that we observed.

Our results are also informative about the time course of reference resolution as a function of multiple grammatical, information structure and reference form constraints.

When referring to antecedents that are salient by virtue of both grammatical (subjecthood) and information structure (fronting) constraints, pronoun references are resolved quickly and efficiently, and allow subsequent material to also be processed quickly. Repeated noun references result in delayed processing of both the reference and the material following it. The processing of the reference in this case involves the consideration of other possible referents as was indicated by the early engagement of the Distractor but not the Unrelated object in the Continue Noun condition in Experiment 1.

When referring to antecedents that are salient by virtue of only grammatical (subjecthood) but not information structure (fronting) constraints, pronoun and noun references are resolved at a comparable speed which is slower than the speed of processing pronoun references in the previous conditions. In these conditions, the processing of nouns but not pronouns leads to the consideration of other possible referents later in the sentence. It therefore appears that the processing of pronouns in

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these conditions is simply slowed, but the processing of nouns involves later verification and consideration of alternative referents.

When referring to antecedents that are salient by virtue of only information structure (fronting) but not grammatical (subjecthood) constraints, pronoun references are resolved quickly and efficiently. Disadvantage does not allow subsequent material to also be processed quickly as in the Continue conditions. Instead, subsequent processing is accompanied by the consideration of alternative referents for the pronoun. Repeated noun references result in delayed processing of the reference but do not lead to the consideration of other possible referents.

When referring to antecedents that are not salient (non-subjects, not fronted), pronoun references are resolved slowly and delay the processing of subsequent information. This delay is not associated with the consideration of alternative referents. Noun references also result in delayed processing that involves the consideration of other possible references, but this does not delay the processing of subsequent material.

Overall, when pronouns refer to non-salient antecedents, there is no indication for the consideration of alternative referents. This is not the case for nouns the processing of which can involve the consideration of alternative referents regardless of the salience of the referent. We can therefore conclude that the processing of nouns and pronouns is differentially affected by grammatical and information structure constraints, and is not compatible with complementary distribution of the two forms.

In summary, the results of our study show that fronting, an information structure constraint, is an effective salience enhancer that can affect anaphor processing independently of subjecthood. These results also show that information structure effects

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on repeated noun anaphors and pronouns are not complementary. This suggests that the RNP as a marker of salience might not be a single simple effect, but instead be a family of related effects that occur in different time frames. Our as well as others` future work with the visual world paradigm will help further disentangle these effects, better our understanding of how different constraints interact, and possibly establish precisely for the effects of information structure constraints on referent salience and reference processing.

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