Control and Raising: Gone With(out) a Trace?

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Abstract

PRO is a theoretically attractive empty category that is proposed to fill the subject position in non-finite (control) clauses. The motivation for its existence is mainly based on uniformity because all sentences necessitate a subject and contain a verb phrase that requires distribution of theta roles in accordance to the theta criterion (Chomsky, 1981). The empirical evidence for PRO remains unclear. The processing of control involves an intricate interaction of constraints. Though recent research on control has contributed to the empirical evidence supporting PRO (Nicol and Osterhout, 1988; Osterhout and Nicol, 1988; Walenski, 2002), it is difficult to find reliable effects that are comparable to the more robust findings on trace reactivations (Nicol and Osterhout, 1988; Nicol and Swinney, 1989; Hestvik et al., 2005, 2010).

In this thesis, I present findings on possible reactivation patterns in control sentences, using picture recognition of correct and incorrect PRO antecedents presented at specific test positions. I also compare control sentences with a similar syntactic construction in the main experiment. Raising sentences have a surface structure syntactically similar to control sentences but result from movement. This operation creates a trace position rather than a PRO.

Both experimental studies were designed in the same manner. They are two reaction time experiments in which sentences were presented to a participant, word for word, on a computer screen. At certain test positions throughout these sentences, an image was presented and the participant was asked to decide whether or not the image was presented previously in the occurring sentence in word form. A green button was pressed for 'yes' and a red button was pressed for 'no'. The pilot study lasted a little over twenty minutes per participant while the main experiment lasted approximately fifteen minutes.

The pilot experiment sampled priming effects compared to a baseline defined by position from 20 participants. It included object and subject control test sentences and filler sentences. The images were presented randomly at three test positions illustrated in the examples below. The positions were either (1) before or (2) after the infinitive marker or (3) at the end of the sentence. These positions represent the position of PRO in (1) S-structure or (2) D-structure and an unrelated position (3).

Object control:
Flodhesten frarådet alligatoren (1) å (2) gå til festen (3).
The hippo warned the alligator (1) to (2) go to the party (3).

Subject control:
Alligatoren lovet sjiraffen (1) å (2) bade i sjøen snart (3).
The alligator promised the giraffe (1) to (2) bathe in the sea soon (3).

Results indicated a significant effect of priming, a significant two-way interaction effect between priming and control type, and a significant three-way interaction effect between control type, priming type, and test position. Syntactic priming led to a speedup in reaction time for subject control in position two and three. For object control, syntactic priming led to a speedup in reaction time in position one.

When focusing exclusively on syntactically primed sentence presentations, the effects of position remained the same, except for position three. Position three became largely slower in the subject control condition. Position two remained the fastest position of antecedent reactivation for subject control. Position one remained the fastest for object control. Throughout the statistical analysis, passive constructions were found to affect the processing of control.

The main experiment sampled reaction time data from 62 native speakers of Norwegian. The test positions were reduced to position one and two because they showed larger and more consistent effects in the pilot study. Position one is the position before the infinitive marker where we would expect to find either PRO or a trace in the case of a raising sentence. Position two is the position after the infinitive marker where we suspect the reader first notices the empty category. I used five sentence conditions, three control types and two raising types. Examples of these constructions are shown below and the experimental test positions are marked.

Subject control (2 possible antecedents):
Elefanten skylder sjiraffen (1) å (2) lage lunsj til dem begge.
The elephant owes it to the giraffe (1) to (2) make lunch for both of them.

Subject control (1 possible antecedent):
Apekatten lærer (1) å (2) sprute vann ut av nesen.
The monkey learns (1) to (2) squirt water out of the nose.

Object control:
Elefanten tillater sjiraffen (1) å (2) plukke blomster i hagen.
The elephant allows the giraffe (1) to (2) pick flowers in the garden.

Subject-to-subject raising:
Alligatoren synes (1) å (2) fange fisk til frokost hver dag.
The alligator seems (1) to (2) catch fish for breakfast every day.

Subject-to-object raising:
Bananen antar apekatten (1) å (2) være god til middag.
The banana, assumes the monkey (1) to (2) be good for dinner.

The results indicated significant effects for condition, supporting differences in processing between control and raising structures. A pairwise comparison of condition showed other significant effects based on the sentence conditions being compared. Subject-to-subject raising and subject (2) control showed a significant interaction effect for position and condition. Subject-to-object raising and subject (2) control showed the same significant effect but also one for position.

Position two showed speedup effects for subject control when syntactically primed, similar to the findings of the pilot study. Position one again showed speedup effects for object

control; however, when assigned a non-syntactic priming (incorrect PRO antecedent presentation) baseline, position two showed a large speedup in reaction time for both subject and object control.

Generally, control sentence conditions displayed a faster reaction time and antecedent reactivation in position two, after the infinitive marker.

Subject-to-subject raising showed a faster mean reaction time in position one. I found position to have almost no effect on subject-to-object raising, though position two was slightly faster. Considering the constraints on subject-to-object control in Norwegian, further discussed in the background section of this thesis, it is possible that the selection of constructions used in this experiment affected the processing of this condition.

The combination of the results from the pilot and main experiment provides evidence that the reactivation effect of PRO can be replicated. Control structures show reactivation effects after the infinitive marker in the sentence. This further supports the idea that control and raising are empirically separate syntactic phenomena and that they are processed in different ways. The effects of position could mean that the syntactic structure of control clauses differ from the typical theoretical representation of PRO before the infinitive marker (Radford, 2004). Can a subject remain within a verb phrase instead of moving to the specifier of the tense phrase? Can PRO be more than just a determiner phrase?

This thesis will discuss the possible theoretical implications that the results have on control structures. The discussion will range from their overall syntactic structure to a suggested universal theory of control. I will also consider the cognitive faculties employed during control processing. An overview of the procedural and structural accounts of processing will be given in relation to control. Finally, I will provide suggestions for future research on the topic.

Sammendrag

PRO er en teoretisk attraktiv tom kategori som brukes for å fylle subjektposisjonen i ikke-finitte kontrollsetninger. Motivasjonen for eksistensen av PRO er hovedsakelig basert på ensartethet ettersom alle setninger krever et subjekt og inneholder en verbfrase som krever fordeling av theta-roller etter theta-kriteriet (Chomsky, 1981). Det empiriske grunnlaget for PRO er derimot uklart. Prosesseringen av kontroll involverer innviklede samspill mellom begrensninger. Selv om nyere forskning på kontroll har bidratt til å finne empirisk belegg for PRO (Nicol and Osterhout, 1988; Osterhout and Nicol, 1988; Walenski, 2002) så er det vanskelig å finne pålitelige effekter som er sammenlignbare med mer robuste funn på trace reactivations (Nicol and Osterhout, 1988; Nicol and Swinney, 1989; Hestvik et al., 2005, 2010).

I denne avhandlingen legger jeg frem funn av mulige reaktiveringsspor i kontrollsetninger. Dataene er samlet inn ved bruk av bildegjenkjenning av korrekte og ukorrekte PRO forledd som blir presentert i spesifikke posisjoner. I hovedeksperimentet sammenligner jeg også setninger med lignende syntaktisk struktur. Setninger med syntaktisk løfting har en overflatestruktur som er syntaktisk lik kontrollsetninger, men som har sitt utspring i bevegelse. Denne bevegelsen skaper en sporposisjon heller enn PRO.

De to eksperimentelle studiene hadde samme utforming. De er reaksjonstideksperimenter der setninger ble presenterte for deltakere, ord for ord, på en dataskjerm. I spesifikke posisjoner i disse setningene ble et bilde vist på skjermen og deltakeren fikk i oppgave å avgjøre om bildet ble presentert tidligere i setningen i form av et ord. En grønn knapp ble brukt for å svare 'ja' og en rød knapp ble brukt for å svare 'nei'. Pilotstudien varte i litt over 20 minutter per deltaker mens hovedeksperimentet varte i ca. 15 minutter per deltaker.

Piloteksperimentet samlet data om primingeffekter sammenlignet med en grunnlinje bestående av syntaktisk posisjon, fra 20 deltakere. Eksperimentet inkluderte bare setninger med subjektkontroll og objektkontroll, og fyllsetninger. Bildene ble presentert tilfeldig i tre forskjellige posisjoner, illustrert i eksemplene nedenfor. Posisjoner var enten (1) før eller (2) etter infinitivsmarkøren eller (3) i slutten av setningen. Disse posisjonene representerer posisjonen til PRO i (1) S-struktur eller (2) D-struktur og i en urelatert posisjon (3).

Objektkontroll:

Flodhesten frarådet alligatoren (1) å (2) gå til festen (3).

Subjektkontroll:

Alligatoren lovet sjiraffen (1) å (2) bade i sjøen snart (3).

Resultatene viste en statistisk signifikant effekt for priming, en signifikant toveis-interkasjon mellom priming og kontrolltype, og en signifikant treveis-interaksjon mellom kontrolltype, primingtype og testposisjon. Syntaktisk priming førte til raskere reaksjonstider for subjektkontroll i posisjon to og tre. Syntaktisk priming førte til raskere reaksjoner i posisjon en for objektkontroll.

Når fokuset var rettet mot utelukkende syntaktisk primede setningspresentasjoner var effekten for posisjon den samme, med unntak av i posisjon tre. Posisjon tre var merkbart tregere ved subjektkontroll. Posisjon to forble den raskeste posisjon reaktivering av forleddet ved subjektkontroll. Posisjon en forble den raskeste for objektkontroll. I hele den statistiske analysen var det tydelig at passiv hadde en effekt på prosesseringen av kontroll.

Hovedeksperimentet samlet inn reaksjonstidsdata fra 62 morsmålstalende nordmenn. Testposisjonene ble forenklet til posisjon en og posisjon to fordi disse posisjonene hadde større og mer pålitelige effekter i pilotstudien. Posisjon en er posisjonen før infinitivsmarkøren der man vil forvente å finne enten PRO eller et spor i en setning med løfting. Posisjon to er posisjonen etter infinitivsmarkøren der vi mistenker at leseren først legger merke til den tomme kategorien. Jeg brukte fem setningsvariabler, tre kontrolltyper og to løftingstyper. Eksempler på disse konstruksjonene er vist nedenfor og de eksperimentelle testposisjonene er markert.

Subjektkontroll (2 mulige forledd.):
Elefanten skylder sjiraffen (1) å (2) lage lunsj til dem begge.

Subjektkontroll (1 mulig forledd):
Apekatten lærer (1) å (2) sprute vann ut av nesen.

Objektkontroll:
Elefanten tillater sjiraffen (1) å (2) plukke blomster i hagen.

Subjekt-til-subjektløfting:
Alligatoren synes (1) å (2) fange fisk til frokost hver dag.

Subjekt-til-objektløfting:
Bananen antar apekatten (1) å (2) være god til middag.

Resultatene viste signifikante effekter for setningstype, som gir støtte til at det er forskjell i prosessering mellom kontroll og løfting. En parvis sammenligning av variabler viste andre signifikante effekter basert på de syntaktiske forholdene som ble sammenlignet. Subjekt-til-subjektløftning og subjektkontroll (2) hadde signifikante interaksjoner for posisjon og setningstype. Subjekt-til-objektløfting og subjetkontroll (2) hadde samme signifikante effekt, men også en effekt for posisjon.

Posisjon to hadde raskere reaksjonstider ved subjektkontroll ved syntaktisk priming, sammenlignbart med funnene i pilotstudiene. Posisjon var igjen raskere ved objektkontroll i posisjon en, men ved ikke-syntaktisk priming (ukorrekt presentasjon av forleddet til PRO) grunnlinje utviste også posisjon to raskere reaksjonstider for både subjektkontroll og objektkontroll.

Generelt utviste kontrollsetningene raskere reaksjonstider og reaktivering på forleddet i posisjon to, etter infinitivsmarkøren.

Subjekt-til-subjektløfting utviste raskere reaksjonstider i posisjon en. Jeg oppdaget at posisjon hadde nesten ingen effekt ved subjekt-til-objektløfting, men posisjon to var litt raskere. Tar man begrensningene på subjekt-til-objektløfting i norsk i betrakting, som er diskutert videre i bakgrunnsdelen av avhandlingen, så er det mulig at utvalget av setninger har hatt en påvirkning på hvordan deltakere prosesserte disse setningene.

Når man kombinerer resultatene fra piloteksperimentet og hovedeksperimentet ender man opp med data som viser at reaktiveringseffekter av PRO kan repliseres. Kontrolstrukturer viser reaktiveringseffekter etter infinitivmarkøren i setningen. Dette gir videre støtte til tanken om at kontroll og løfting er empirisk forskjellige syntaktiske fenomener og at de prosesseres på forskjellige måter. Effekten for posisjon kan bety at den syntaktiske strukturen i kontrollsetninger er forskjellig fra typiske teoretiske beskrivelser av PRO før infinitivsmarkøren (Radford, 2004). Kan et subjekt forbli inni en verbfrase istedenfor å flytte til en annen posisjon høyere i det syntaktisk treet? Er det mulig at PRO bare er en determinativsfrase?

Avhandlingen tare for seg mulige teoretiske implikasjoner som de empiriske resultatene har for kontrollsetninger. Diskusjonen går fra den helhetlige syntaktiske strukturen til en foreslått universell teori for kontroll. Jeg vil også ta for meg de kognitive fakultetene som brukes i prosesseringen av kontroll. Et oversyn over prosessuelle og strukurelle forklaringer av prosessering vil også gis for kontroll. Til slutt vil jeg komme med forslag til videre forskning på temaet.

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Chapter 1

Introduction

1.1 Control: The PRO in Grammar

A controversial subject in theoretical linguistics is the grammatical phenomenon of control. It originates within the Binding Theory (BT) of Generative Grammar that stemmed from the works of Chomsky (1957, 1965, 1981). PRO is a special kind of null determiner phrase (DP) that is often, but not always, assigned null case (Chomsky and Lasnik, 1993; Sigurðsson, 2008; Sportiche et al., 2013). It occupies the subject position of the embedded clause of a sentence that contains a control verb in the matrix clause.

The predicates of a control sentence contain thematic properties which require an additional inter-sentential argument. This is where PRO comes in. PRO is necessary in order to fulfill the theta criterion, which states that each argument in a sentence can have one and only one theta role and each theta role can have one and only one argument (Chomsky, 1981). In spite of this, PRO still causes much conflict in syntactic theory (Carnie, 2013). This indicates that it is poorly understood and needs greater support from empirical data.

The syntactic and semantic processing that occurs within control sentences is not yet fully understood. Even so, evidence is growing for the case of PRO being more than just a syntactic phenomenon (Nicol and Swinney, 1989). This could go a long way in explaining the discrepancies present in the PRO theorem. In order to consider the possible semantic and pragmatic aspects of PRO, more experimental work needs to be done using a greater variety of methods and techniques. This appears to be the next step to take in finding an explanation for this phenomenon called control.

1.2 Raising: Finding the Traces

Raising, though seemingly less controversial than control, has had a long history of theoretical changes and disagreements. It became its own concept in the original theory of Rosenbaum (1967) in which he called it 'Pronoun Replacement'. He considered it to be a rule that caused the subject noun phrase (NP) of a *that* complement of specific verbs (B-verbs) to move out of the subordinate clause and into the object NP position of the main clause. The more recent terminology for this in literature is *subject-to-object raising*. Rosenbaum then claimed that Pronoun Replacement worked with another set of verbs (A-verbs), where the same NP movement would occur but it would move to the subject NP position in the main clause. This has become know as *subject-to-subject raising*.

When compared to control, it seems the two are processed similarly. It is difficult to distinguish between the surface structures of these sentence constructions, but it is important to note that raising does not involve PRO but rather a trace as a result of syntactic movement. The trace is left in the subject NP position in the subordinate clause (Postal, 1974). Raising traces are unpronounced just like PRO. The fact that raising is formed by movement has major consequences on the assignment of theta roles in these sentences. These consequences are simply that theta roles can be assigned appropriately and according to theory, unlike in control sentences if they were to form from movement.

1.3 Research Introduction and Hypotheses

The experimental work presented in this thesis will consist of two separate experiments conducted using reaction time measurements. Both experiments were designed using semantic priming paradigms and image probe stimuli. I focused on measuring the possible reactivation of PRO antecedents at specific points throughout the sentence presentation. Three test positions were included in the pilot study, before and after the infinitive marker and at the end of the sentence. Two test positions were included in the main experiment, before and after the infinitive marker. The second and larger experiment also measured the possible reactivation of raising trace referents. This research was completed because of the need for more empirical evidence with higher quality when it comes to the theoretical work on control and raising in the field of linguistics.

In analyzing this data, I will compare the different sentence structure data and the priming effects found in each condition. The significant effects and trends found for the experimental factors will provide support for the theoretical differences between control and raising. They will also enable the current processing hypotheses to be considered in the light of new data.

The main working hypotheses to be considered in relation to theoretical matters are:

(1) Control and raising are different syntactic phenomena, as shown by their processing difference.

(2) Control and raising are the same syntactic phenomena, as shown by their processing similarities.

(3) Syntactic priming does not effect the reaction time of PRO antecedent reactivation. Control is not only held by syntactic constraints.

(4) Syntactic priming does not effect the reaction time of raising trace referent reactivation. Raising is not only held by syntactic constraints.

The main null and alternative hypotheses to be considered in relation to language processing are:

(5) No reactivation of PRO antecedents occurs during the processing of control sentences.

(6) No reactivation of raising trace referents occurs during the processing of raising sentences.

(7) Reactivation of PRO antecedents occurs before/after the infinitive marker in a control sentence.

(8) Reactivation of raising trace referents occurs before/after the infinitive marker in a raising sentence.

The null hypotheses in (5) and (6) stand as default if no effects and differences are recorded for reaction times. Rejecting a null hypothesis indicates that there is an observation that cannot be explained by assuming no effects. These hypotheses will be considered once more after the presentation of the results in Chapter 4.

Though there exists various processing theories in literature, the main conclusions drawn from the collected data will be based on the Trace Reactivation hypothesis (Nicol and Swinney, 1989). This hypothesis assumes that empty categories act similarly to pronouns and anaphors and their antecedents will reactivate at their PRO or trace positions. Other theories of processing will be considered in Chapter 2, but the design of these experiments was based on the concept of processing specifically from the Trace Reactivation hypothesis.

1.4 Summary of Results

The two reaction time experiments introduced in this thesis have shown results that provide insight on the processing of both control and raising construction in Norwegian. Significant effects of priming were recorded across all levels of test sentence conditions. Both studies indicated a reactivation effect of the correct PRO antecedent for subject control in position two, after the infinitive marker.

The pilot study showed a faster mean reaction time (RT) for object control when syntactically primed in position one, before the infinitive marker. Subject control displayed reactivation effects in test positions two and three, but the effects in position three diminished when I took out the interaction effects associated with priming.

Reactivation of raising trace referents in the main experiment generally showed greater priming in position one. On the other hand, reactivation of control antecedents displayed priming in position two. The effects of position and condition recorded from this experiment support the hypothesis that control and raising are separate sentence constructions. The coreference assignment that takes place during sentence processing for these two syntactic phenomena rely on different mechanisms. I will present the results in more detail in Chapter 4, followed by the implications in the discussion chapter.

1.5 Thesis Outline

This thesis will be organized by chapters. Chapter 1 has laid out the main issues motivating the experimental style as well as the topics of research. It gives a basic explanation of the topics and the research design used to test the mentioned hypotheses.

Chapter 2 will build on the theoretical background of control and raising. We will explore the similarities and differences between control and raising in theory. This includes the constraints imposed on these phenomena by syntactic theory. Specific constraints on raising constructions in Norwegian will be addressed. The previously mentioned Trace Reactivation Hypothesis will be discussed along with other theories of processing. The chapter will end with the presentation of relevant previous experimental research.

Next, Chapter 3 will lay out the experimental methods used for both the small pilot study and the main experiment. It will begin with an explanation for the choice of experimentation techniques and then move on to illustrate the design and procedure of both experiments. Data validity will be addressed followed by the methods of analysis.

Chapter 4 will commence with the presentation of the results from the pilot and main experiment. This chapter will include an in-depth statistical analysis completed using R. Significant results and data trends will be described for each experiment. The control and raising data will be compared from the main experiment and, lastly, I will provide a comparison of the various levels of control.

Chapter 5 includes an in-depth explanation of data quality control. I will discuss the distribution of data and show how this was considered in my statistical analysis. This chapter will provide an outlier analysis and support for the exclusion of certain data points.

A discussion of the results will take place in Chapter 6. This consists of a consideration of the theoretical implications posited by the experimental results. The significant effects found during the statistical analysis will be addressed individually in relation to the original hypotheses. The end of this chapter will suggest a unified theory of control inspired by the findings presented in this thesis.

Chapter 7 will provide suggestions for further research. This will not include an exhaustive list but rather some ways to test possible hypotheses stemming from my results. Finally, I will provide a conclusion bringing together the ideas and results addressed throughout the previous chapters.

Chapter 2

Theoretical and Experimental Background

2.1 Theoretical Background

2.1.1 The History of Control

PRO is very much a linguistic phenomenon based in theory. It was originally introduced by Chomsky (1981) in order to fill a gap in an important syntactic theory in Generative Grammar, *the theta criterion*. In addition to phrase structure and x-bar rules, the grammar has the theta criterion which acts as a constraint ensuring that these rules do not over-generate and produce ungrammatical sentences. The theta criterion constrains the assignment of theta roles to arguments and arguments to theta roles. Under this criterion, each argument can have *exactly one* theta role and each theta role can have *exactly one* argument (Chomsky, 1981). A theta role can be one or more thematic relation (agent, theme, goal, etc.) that is assigned to an argument. The thematic relation(s) of an argument describe the semantic characteristics of the argument while the theta role is the syntactic representative of an argument in the argument structure of a verb.

In order to illustrate the original discrepancies found in the theta criterion when control sentences were first considered, two example sentences will be examined below. The best way to do so will be by creating theta grids. The first sentence shown in (1) is a non-control sentence.

(1) John_i placed $[\text{the flute}]_j$ on $[\text{the table}]_k$.

place

Source / Agent DP	Theme DP	Goal PP
i	j	k

(Carnie, 2013)

The boxes in the top row of the theta grid are the theta roles required by the verb *place*. Inside of these boxes, you can see the thematic relations. The bottom row of boxes contain the indices associated with each theta role. These indices are assigned to the corresponding arguments in the sentence in (1). Now we will examine the theta grid of a control sentence in (2).

(2) Jean$_i$ persuaded Robert$_{m\ j}$ [to leave]$_k$.

leave

Agent DP
j

persuade

Agent DP	Theme DP	Proposition CP
i	m	k

(Carnie, 2013)

Similar to the sentence in (1), theta roles are assigned in (2) using indices. As the sentence stands now, the distribution of theta roles violates the theta criterion. *Robert* cannot receive two theta roles, one from each verb. This is where PRO comes in and acts as the receiver of the theta role of *leave*. The theta grid remains the same, but the syntax of the sentence changes to that in (3). Though not explicitly shown by indices, PRO is still coreferent with Robert.

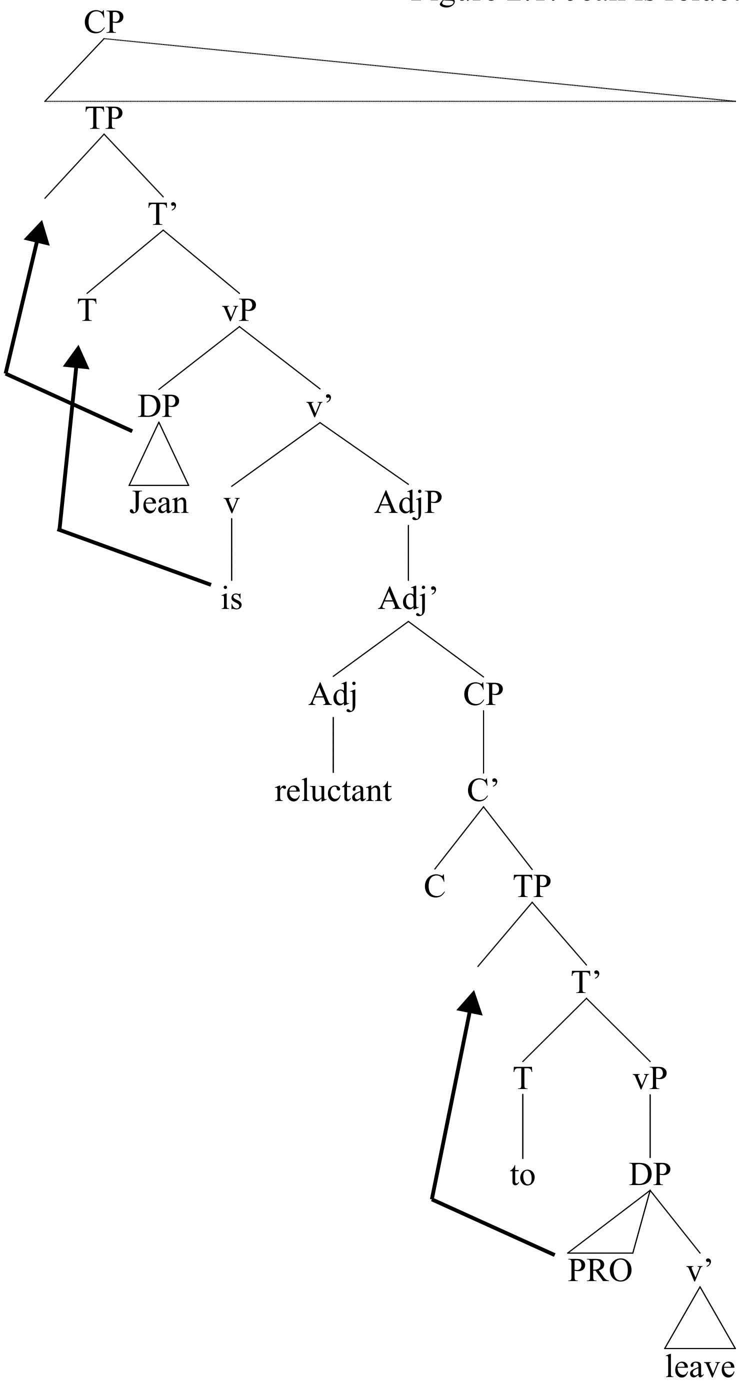
(3) Jean$_i$ persuaded Robert$_m$ [PRO$_j$ to leave]$_k$.

As previously mentioned, PRO is a null element that acts as the subject DP in non-finite clauses. Both (2) and (3) have the same surface structure, but example (3) shows the syntactic structure, including all null elements. The addition of PRO to control sentences seems to solve the violation of the theta criterion that previously occurred within control sentences. Unfortunately, this new element brought about new theoretical issues, violations of the Binding Theory and the Case filter.

The Government and Binding (GB) theory (Chomsky, 1981) shows PRO appearing in two different positions in D-structure and in S-structure. D-structure is the underlying form of a sentence before movement occurs. S-structure is the output generated from the use of transformational rules, which results in movement and a grammatically correct sentence (Carnie, 2013). The clausal positioning of PRO has been assumed to be the typical subject position, the specifier position of the tense clause, based on the subject-like characteristics of PRO and the Extended Projection Principle (EPP) (Radford, 2004), which requires that every clause have a subject (Rothstein, 1983).

In the GB theory, subjects appear in the specifier position of the tense phrase (spec-TP) in S-structure. This is before the infinitive marker. They originate, however, in the specifier position of the verb phrase (spec-VP) in D-structure. This is after the infinitive marker (Carnie, 2013). Therefore, in order for the EPP to be satisfied, movement of PRO from spec-VP to spec-TP must occur. The infinitive marker, *to*, is considered to have an EPP-feature that must be checked and realized by this movement. Consequently, PRO is considered to be located before the infinitive marker after this movement. There are linguists, though, who argue that the actual position of PRO is its original VP-internal position (Baltin, 1995). I have included a syntactic tree for illustration of these PRO positions and movements below in Figure 2.1.

Figure 2.1: Jean is reluctant to leave.



(Carnie, 2013)

The attempts to characterize PRO within GB theory have been unsuccessful. A main part of this theory is the Binding Theory which encompasses three different noun types: anaphors, pronouns, and R-expressions. Of these three types, PRO shows characteristics of two but only *sometimes*. PRO can take on the properties of a pronoun or an anaphor based on what kind of PRO it is. Arbitrary PRO is not controlled by a referent and gets its meaning from outside of a sentence. I have included an example below in (4). Non-arbitrary PRO can have obligatory control, necessitating referent control, or optional control, allowing for the possibility of referent control (Carnie, 2013). This is the type of control that I focus on in this thesis. The problem is that PRO has the possibility to be free (not controlled), optionally controlled, or necessarily controlled. The first two qualities smell strongly of a pronoun; on the other hand, the last one reeks of an anaphor.

(4) PRO_{arb} to find a new mate, go to a dating service.

(Carnie, 2013)

The solution to this problem was the declaration of a special status for PRO, devised by Chomsky and Lasnik (1993). The PRO theorem was introduced and along with it came certain characteristics that were attributed specifically to PRO. To solve the problem stemming from the Binding Theory, it was decided that PRO *cannot be governed*. Something governs something else if it c-commands it and there is no item or word in between that intervenes. This meant that it no longer had a governing or binding domain and could no longer be restricted by the Binding Theory. The formal definitions of c-command and government from Carnie (2013) are presented in (4).

(5) *C-command*: Node A c-commands node B if every node dominating A also dominates B, and neither A nor B dominates the other.
Government: Node A governs node B if A c-commands B and there is no node G such that G is c-commanded by A and G asymmetrically c-commands B.

After this, the problem became the Case filter that requires all DPs to be marked with a case. Since PRO could not be governed, PRO could not receive case. As a result, the PRO theorem also included a segment stating that PRO has a special null case, checked by non-finite tense markers. Though these characteristics of PRO were reasonable to assume when considering English grammar, linguists were quick to point out that this was not the case across other languages (Sigurðsson, 2008; Sportiche et al., 2013).

In addition to PRO's complicated outer layer, there is an inner layer containing further subcategories. The first is called subject control and this is when PRO is the co-referent of the matrix clause subject. The second is called object control and involves co-reference between PRO and the object of the matrix clause. This division exclusively accompanies instances of PRO that necessitate control. To illustrate, examples are shown in (6) below, (6a) being object control and (6b) being subject control.

(6) a. Louis begged $Kate_i$ PRO_i to leave her job.
b. $Louis_k$ begged Kate PRO_k to be allowed PRO_k to shave himself.

(Carnie, 2013)

Nonetheless, there are still layers of PRO that evade explanation. Is it possible to receive insight into PRO's characteristics by looking at its linguistic environment? The main predicate raises suspicions. After all, it is to blame for the addition of PRO in the first place. Look at example (6) again. Notice how the same verb with the same thematic properties was used in both control situations. The verb *beg* can also be used in sentences not containing PRO (7a) or with a reduced number of PRO DPs (7b). Therefore, it cannot be assumed that control is completely a thematic property orchestrated by the main predicate since the same predicate can be used to produce each of the example sentence structures in (6) and (7).

(7) a. Louis begged Kate that she leave her job.
b. Louis$_k$ begged Kate that he be allowed PRO$_k$ to shave himself.

(Carnie, 2013)

Another aspect of PRO's linguistic environment that could be a plausible suspect is the sentence structure in which it appears. It is possible that referent assignment is heavily based on linear distance. The Most Recent Filler Strategy (Frazier et al., 1983) has been considered before to explain the filling of gaps by automatic co-indexation with the most recent possible antecedent. However, as illustrated in (6), control can fluctuate from the object or subject of a main clause with two possible controllers simply by the switch of a verb or the sentence structure in the subordinate clause.

It seems that even though PRO is still mysterious in its motivations and characteristics, theory has a generally set view of how it is represented within syntactic structure; nevertheless, this is wrong. In addition to the already described view and theories of control, there are those that are completely stripped of PRO (Janke, 2003; Hornstein, 1999). One view which is of particular interest in this paper is that control works the same as regular NP movement traces. Hornstein creates a new set of theoretical assumptions to replace those from Generative Grammar:

- Theta roles are features on verbs.
- Greed is Enlightened Self Interest.
- A DP/NP receives a theta role by checking a theta feature of a verbal/predicative phrase that it merges with.
- There is no upper bound on the number of theta roles a chain can have.
- Sideward movement is permitted.

The results of Hornstein's analysis do not leave much room for differences between the processing of control and raising (see section 2.1.2 for a discussion about raising). This is something that must be considered within this thesis even though the original testing hypotheses were formed using the previously mentioned view of control. The prediction from Hornstein's analysis is that raising and control should be virtually indistinguishable in processing and, as a consequence, there should be no significant differences in reaction time priming effects. The consequences of this description of control structures and how it can be evaluated with the help of empirical data will be addressed later in this thesis.

As the theoretical views on control evolve, we are beginning to see linguists calling for the elimination of government in the distribution of null complementizers, such as PRO (Bošković and Lasnik, 2003). What does all of this mean for PRO? Although PRO's role in sentence structure is described in theory in quite some detail, linguists are still uncertain about its role and even its existence. Consequently, the status of PRO is uncertain. Any further development necessitates theoretical testing, including testable predictions from competing theories.

2.1.2 History of Raising

Raising structures were not originally recognized as the syntactic constructions that they are today. These structures originally gained the interest of Lees (1960) who noticed the phenomenon of raising occurring in certain passive sentences. As a result, he assumed that the issues that he encountered while trying to describe and characterize these constructions must be due to passivization. An example of this sentence type is provided in (8).

(8) She is said to be educated.

Postal (1974)

This assumption led Lees to consider these examples of what is now called raising to be a type of second passive of *that*-clause complements. In order to explain the formation of these constructions, Lees proposed a Second Passive rule. This rule allowed the subject NP of embedded clausal objects, accompanied by specific verbs, to be passivized. It was called the Second Passive rule because there already existed a passive construction which involved passivization of the whole object of verbs. Though this rule seemed to hold for Lees' main example, it did not hold for well-formed examples or other raising verbs.

Although Lees' characterization of raising as a second passive was not entirely correct, it took some years before this construction was looked at again. Rosenbaum (1967) took on the challenge of discussing the flaws in Lees' reasoning along with a new suggestion on how to understand the underpinnings of raising. Instead of the Second Passive rule used by Lees, Rosenbaum suggested a new rule called Pronoun Replacement. This rule was focused on instances of what is now called subject-to-object raising. Pronoun Replacement was said to take the subject NP of the *that* complements of certain verbs (B-verbs) and move them into the matrix clause. This movement created a derived subordinate object NP.

Rosenbaum went on to say that there were even more verb types (A-verbs) that supported the Pronoun Replacement rule. These verbs create constructions that today are called subject-to-subject raising. In these sentences structures, the complement subject NP raises into the matrix clause subject position. Rosenbaum attempted to make both of these construction types possible with only the use of the Pronoun Replacement rule. The explanation involved the Pronoun Replacement rule operating on the output of Extraposition. Though the idea of a single rule being able to achieve sentences with both derived objects and derived subjects was popular, the Pronoun Replacement rule was not.

Under critique from Ross and Lakoff (1967), Rosenbaum's Prounoun Replacement rule was dissected and ruled out. The examples and arguments used to do so are no longer as strong as they were in 1967; nonetheless, the evidence still proves their case. A couple of their arguments against Rosenbaum's theory of the formation of these raising structures have caused the undoing of the Pronoun Replacement rule. One is the fact that raising sentences can have both gerundive and infinitival complements. Rosenbaum himself said that gerundive complements generally do not undergo Extraposition and this would mean that they cannot undergo Pronoun Replacement to form a raising sentence. This is discussed at length by Postal (1974), along with the Shift operation and island constraints.

The other opposing point used to discredit the idea of Pronoun Replacement is simply the fact that operating on the output of Extraposition often yields derived constituent structures that are incorrect. Lakoff then decided to make his own attempt at a unitary rule for raising constructions but failed. It was unpublished and mostly ignored. The idea of a unitary rule for raising still remained though and the next researcher to pursue this topic was met with more acclamation.

McCawley (1968) presented a new way to explain raising and the possibility of using one rule when dealing with both B- and A-verbs. This also involved a change in how theory presented English sentence structures in general. Instead of using a typical underlying structure of NP + Verb like Rosenbaum and Lakoff before him, McCawley introduced a solution using verb-initial sentence structures. His solution assumes that the Subject Formation rule is postcyclic and that raising is cyclic. A generic version of the syntactic structure of a raising sentence is shown in (9).

(9) X Verb (NP) $[_{NP}$ $[_{S}$ Verb NP Y]] Z

The above structure can be used to visualize McCawley's theory of what occurs during the transformation of both B-verb and A-verb raising sentence structures. When a B-verb is present in the matrix clause, the optional NP in the matrix clause is included and the NP from the subordinate clause moves to the right of the subject NP of the matrix clause to become the object NP of that clause. When an A-verb is present in the matrix clause, the optional NP is not included and the NP in the subordinate clause moves to become the subject of the matrix clause. A final transformation rule, Subject Formation, is then used to create the NP-initial structure that is typical of the English language. This remains as one of the accepted views of the creation of raising structures; however, another theory has gained popularity, especially within Generative Grammar.

This popular theory of raising and the underlying rules behind it comes from the work of Chomsky (1981). Chomsky's original ideas on raising were not the same as they are in Generative Grammar nor the minimalist framework today. With his first remarks on raising, he denounced the existence of B-verb raising structures (Chomsky, 1972). This was some years after McCawley's theory of raising was published, but Chomsky did not address the idea of a verb-initial evaluation of sentence structure. Instead, he solved the issue of encompassing raising under one rule by eliminating one type of raising. His view on raising has changed overtime though.

Those linguists who have continued to follow Chomsky's theories of grammar now discuss subject-to-object raising (B-verbs) and subject-to-subject raising (A-verbs) as being formed in the same manner. The concept of phrase structure rules was develop within the Generative Grammar framework (Chomsky, 1981) and this enabled linguists to look at raising structures in a different way than before. Under this view of raising, the subject of a raising sentence moves out of the subordinate clause and into either the object position (B-verbs) or subject position (A-verbs) of the matrix clause. This is similar to the claims made by Rosenbaum, but the movement of these items is motivated differently. In order to illustrate these motivations and how they work throughout sentence structure, an example of each type of raising is shown in (10), along with the theta grid for each verb.

(10) a. Subject-to-object raising: Jean_i wants Brian_m $[t_m$ to $\text{leave}]_k$.

want

Experiencer DP	Proposition CP
i	k

leave

Agent DP
m

b. Subject-to-subject raising: Jean_n is likely $[t_n$ to $\text{leave}]_j$.

is likely

Proposition CP
j

leave

Agent DP
n

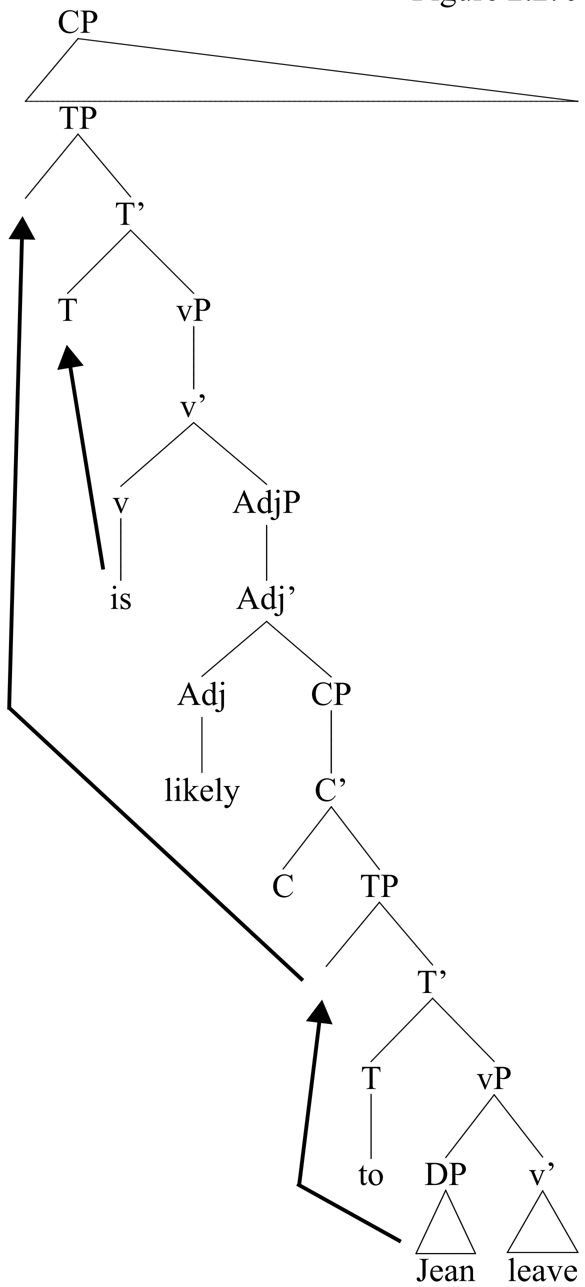
(Carnie, 2013)

Right away, we can see differences in the number of theta roles that require argument assignment. In (10a), the experiencer role is assigned to the NP *Jean* and then a CP is inserted after the verb. The subordinate verb *leave* assigns the agent role to the NP *Brian* and everything is in order. Why does *Brian* move from the subordinate clause subject position to the matrix clause object position then? The answer is to be assigned case. The NP receives its theta role from the lower clause but has to move higher in the syntactic tree, and into the matrix clause, to be assigned case.

In (10b), the movement of the NP *Jean* has similar motivations. *Jean* receives an agent theta role from the verb *leave* but cannot receive case in this position. Therefore, it moves out and into the matrix clause. *Jean* is forced to move into the subject position of the matrix clause to satisfy the Extended Projection Principle (EPP). One important aspect of this principle is that all clauses must have subjects (Rothstein, 1983). Consequently, *Jean* is obliged to fill in as the subject of the matrix clause. I have included a syntactic tree structure from Carnie (2013) in Figure 2.2 on the following page in order to illustrate the movement involved in raising structures.

The EPP is also the reason that some raising sentences have an expletive for a subject. Even when a theta role is not available for assignment, an expletive will be inserted in a

Figure 2.2: Jean is likely to leave.



sentence to ensure the existence of a subject. This is called the Expletive insertion rule. An example of this is shown below in (11) where *it* is inserted to satisfy the EPP.

(11) It is likely that Bill_n [t_n likes chocolate].

(Carnie, 2013)

As time goes on, the motivations for raising evolve, but the idea of movement remains. Minimalism has been the newest development in linguistic theory and continues to expand. Under this framework, raising leaves a trace and produces the same movement as described above. The difference is in motivation.

The movement that takes place is caused by the target and not the moving NP itself. In this instance, the item in the sentence that assigns case attracts the NP immediately upon introduction into the sentence. Then the NP moves to take care of the case that needs checking and this process does not need to wait for they cycling of various rules and checks and balances that take place throughout the syntactic structure of a sentence. Chomsky (1993, 1995) begins laying out the foundation for the minimalist program and later further developed ideas of raising (Chomsky and Collins, 2001) based on theories provided by Uriagereka (1998, 1999); Epstein (1999); Lasnik (1995).

In all instances of raising, the DP/NP moves out of the subordinate clause and leaves a trace (t) in the position in which it received its theta role. The moved DP/NP and the trace are the same item and both have the same characteristics. In relation to the control structures which were discussion in 2.1.1, this is a new concept.

Control structures need PRO in order to assign a lingering theta role to an argument. This theta role is different from the one assigned to the DP/NP controller of PRO. That means that they are two separate items with differing syntactic and semantic characteristics. PRO is coreferenced with its controller in the matrix clause, and therefore refers to the same entity in the world, but it does not have the same relationship with this controller as a raising trace does with its matrix clause DP/NP.

Constraints on Raising in Norwegian

The constraints on raising constructions in Norwegian are unique from what are usually considered the general rules of raising, which are often formulated based on the English language. Subject-to-object raising has even been considered to be non-existent in infinitival clauses of certain types of Norwegian verbs. Lødrup (2008) states that this is not true.

A certain constraint called the Derived Object Constraint (DOC) is applicable in subject-to-object raising constructions in Norwegian. This constraint was first observed by Postal (1974) who noticed that the raised object in sentences with specific reflective verbs in English required the object to occupy a different position than it normally would. Even more examples illustrating this constraint have been discovered since (Kayne, 1984). An example is given in (12).

(12) a. *I assure you John to be the best.
b. John, who I assure you to be the best.

(Kayne, 1984)

The DOC is also applicable in a similar way to reflective raising constructions in Norwegian. I have provided a Norwegian example for comparison in (13).

(13) Muskuløse mennesker antok han å være aktive og utholdende.
muscular persons assumed he to be active and tireless
He assumed muscular persons to be active and tireless.

(Lødrup, 2008)

The DOC is considered an important rule for these raising constructions and objects occurring after the matrix verb are generally always violations of Norwegian syntax. According to Lødrup (2008), there are exceptions where verbs might allow the object to sit in the usual object position, but these are rare. This added level in complexity of subject-to-object raising sentences in Norwegian seems to lower their frequency of use in the language.

2.1.3 Theories of Processing

The following hypotheses were taken from Walenski (2002) and will be considered in relation to the experimental work presented in this thesis

1. Trace Reactivation Hypothesis

   The Trace Reactivation Hypothesis has been used to analyze the data collected from various linguistic experiments. Nicol and Swinney (1989) used this hypothesis to explore coreference assignment. They looked at experimental work completed on wh-traces, NP-traces, overt anaphors, pronouns, and PRO (Swinney et al., 1988; Bever and McElree, 1988; Nicol, 1988; Nicol and Osterhout, 1988; Osterhout and Nicol, 1988). This work will be discussed in section 2.2. Hestvik et al. (2010) also designed an experiment on NP-traces in relative clauses and used the concept of trace reactivation to understand the processing of these gaps. Since the reaction time experiments presented in this thesis were based off of the designs of these previous experiments, this hypothesis was incorporated into the overall test design.

   This hypothesis says that the correct antecedent will be selected for, and reactivate at, the trace or PRO position in the syntactic structure. Empty categories are considered to act like covert pronouns or anaphors. If this is the case, we should expect control and raising sentences to be processed in a similar manner. Both the NP raising trace and the PRO should show reactivation before the infinitive marker in the subordinate clause.

2. Direct Association Hypothesis

   This hypothesis suggests that reactivation effects stem from verbs, which are in charge of theta role assignment (Pickering and Barry, 1991; Pickering, 1993). There are no empty categories like PRO in this theory of processing. Control and raising would be considered to be represented similarly and possibly processed similarly as well. Even so, as mentioned previously there is a second theta role being assigned in the subject position of the subordinate clause in control structures. This does not occur in raising sentences as there is only one theta role shared by the subject/object NP of the matrix clause and its trace. The fact that control sentences have a more complex distribution and a greater number of theta roles to assign could lead to a greater processing load for control structures.

3. Levels of Processing Hypothesis

   The levels of processing hypothesis was introduced by Fodor (1993) and discusses the best methods to use when researching specific phenomena. Depending on how syntactic or semantic in nature the processing of an item is, the more likely it is to find effects using certain experimental techniques. Fodor argues that tasks such as cross-modal priming are more sensitive to structural processes. He also adds that effects of PRO and NP-traces could be more semantic in nature. It is possible that priming does not pick up all of the effects of processing control and raising. Even so, there has been previous experimental work using these type of techniques in which effects were successfully uncovered (see section 2.2). Control and raising might be syntactic and semantic in nature and, therefore, produce effects in tasks sensitive to both processes.

4. Thematic Revision Hypothesis

   The thematic revision hypothesis states that priming effects are a result of the revision of thematic information and that the effects show when theta roles are assigned (Fodor and Swinney, 1992; Nicol, 1993). This also points to reactivation not being syntactic in nature. Considering the difference in theta role number and assignment between control and raising structures, this is another interesting hypothesis to incorporate into the experimental design. If a raising trace requires no thematic revision then it should be processed more efficiently and display priming effects facilitating faster reaction times. PRO is a separate item in relation to the NP that it is coreferent with, but it requires revision because a new theta role must be assigned. This would mean that we should find a priming effect that leads to a slowdown in reaction times for control sentences in the PRO position.

   On the other hand, the thematic revision hypothesis assumes that a theta role is immediately assigned to an NP, sometimes simply by guessing. This assignment is later revised or confirmed as new information becomes known. If the subject of the matrix clause is automatically presumed to be the antecedent of PRO in a control clause or the referent of the trace in a raising clause, then this would lead to a speedup in coreference processing if the subject was indeed the correct referent. If not, then a revision is required, and this would lead to a slowdown in coreference processing for both sentence construction types.

5. Depth of Processing Hypothesis

   This final hypothesis focuses on the factor of expectancy. If a complement is less expected then it will be more difficult to process. This ultimately is said to lead to it being processed more deeply and, in turn, easier to recall (Fodor, 1995; Cairns et al., 1981). Under this hypothesis, we would assume that the more complex phenomenon would display *faster* reaction times. Walenski (2002) claims raising constructions to be more complex within his experimental work, in comparison to control, because they display faster processing. Looking at the theoretical background of control and raising, however, makes control seem as if it would be the more complex phenomenon to process.

   This hypothesis was not considered too much during the experimental data analysis because the more complex sentence constructions (those with two possible antecedents) did not show an increase in processing speed. As the general complexity of both control and raising sentences increased, so did the reaction time. It does not seem logical to assume that the complexity of the syntactic phenomenon itself would lead to faster reaction times because the deeper processing may also take time. This hypothesis was included to consider all possible processing strategies though.

In planning the experiments presented in this thesis, I aimed for a minimal contrast between the test sentences and their baseline. The participant's task should ideally be virtually the same for all sentence presentations. For example, the only difference should be whether or not the presented image was coreferent with PRO. This was difficult to accomplish because, at the same time, the experiment must be balanced and avoid repetition effects. We will consider the experimental contrasts and baseline further in Chapter 4.

2.2 Experimental Background

2.2.1 Noun Phrase (NP) Antecedent Reactivation

Hestvik et al. (2010) completed a study on gap filling in NP-trace positions of explicit pronouns in relative clauses. This was completed using traditionally developing and children with Specific Language Impairment (SLI). It was found that immediate gap filling took place in the processing of traditionally developing children but was temporarily delayed in children with SLI. This study showed that pronoun reactivation at trace positions is immediate and that there are specific processing mechanisms associated with this reactivation.

The design of this experiment used a cross-modal picture naming technique. This method was used to create an easier task for the participants. The paradigm presented test sentences audibly to children and images visually. The design of the experiments presented in this thesis were originally based on the one used for this study.

Other experimental work on NP-trace reactivation has used a cross-modal technique to probe for word recognition at various testing points throughout test sentences containing overt anaphora. The results showed significant priming effects only for the correct antecedent of the trace. These results are similar to what I found in my data analysis. This empirical evidence supports the hypothesis that NP reactivation of antecedents complies with syntactic binding constraints (Nicol and Swinney, 1989; Swinney et al., 1988).

2.2.2 PRO Antecedent Reactivation

Though it is more common to find experimental research on overt anaphora, there has been previous research on the processing of control. Nicol and Osterhout (1988), using similar cross-modal techniques as the formerly mentioned experiments, found both possible antecedents showed reactivation at the PRO position. This effect was replicated in another experiment, but at later positions and not the proposed PRO position (Osterhout and Nicol, 1988). The pattern of PRO reactivation seemed to be similar to that of pronoun traces. The timing, however, was delayed in comparison. I would like to point out that both active and passive sentence constructions were used in Osterhout and Nicol's experiments.

The majority of research on coreference processing has been conducted using reaction time experiments. Walenski (2002) combined the results of a cross-modal reaction time experiment with the results of an event-related potential (ERP) study to test the processing differences in control and raising phenomena. The results of the reaction time study of similar design to those discussed previously showed that raising constructions displayed priming before the infinitive marker, which is congruent with results in this thesis. No priming effects were recorded for control constructions. The lack of priming for control sentences led to the conclusion that PRO antecedents have delayed reactivation or that this process does not require reparsing. Walenski's experimental effects were calculated using an unrelated probe baseline.

Walenski discovered no processing load differences for control and raising in the gap position (before the infinitive marker). The second position he tested was before the subordinate clause verb, but it was not the same position tested in my experiments. He created distance between the infinitive marker and the subordinate clause verb using adjectives. Thus, his second testing position was not immediately after the infinitive marker.

Walenski concluded that there were differences between control and raising with relation to processing speed. Both the grammar and parser of these constructions were found to have a dependency between the matrix subject and the onset of the infinitive marker. This finding is also supported by the experimental work in this thesis.

Chapter 3

Experimental Methods

3.1 Reaction Time and Priming

The design utilized in the experimental work presented in this thesis was heavily based on that of Hestvik et al. (2010). Their research involved the investigation of NP traces in gap positions of relative clauses. This was previously mentioned in Chapter 2. Since PRO is considered to be a type of NP, a similar technique to that of Hestvik's was used to test for PRO referent reactivation in control sentences. Raising sentences involve NP traces and so this technique was appropriate for investigating trace referent reactivation in these structures as well. The use of reaction time experiments enabled the testing of reactivation at specific points throughout the test sentences. Measuring the reaction times of participants allowed quality temporal measurements to be recorded. This is important because the processing of control and raising is time sensitive.

The reaction time measurements were taken in response to a decision made by the participant when presented with an image stimulus. In the experiments to be discussed in further detail in the next sections, the presentation of images consistent or inconsistent with the PRO or trace referent at specific syntactic testing positions was used to investigate priming in relation to referent reactivation. Previous experimental work on control has focused on reaction time experiments (Nicol and Osterhout, 1988; Osterhout and Nicol, 1988; Walenski, 2002), often using auditory stimuli or visual word stimuli. Priming data can provide great insight on the processing of an item; however, using this method can sometimes lead participants to over-analyzing their task.

Images were used as priming stimuli in order to create a task that was uniformly easy to understand for all participants. In these experiments, the participants were asked to view an image and decide whether or not the image had been previously referred to by name in the sentence. This process involved tasks such as image recognition, word recall, and decision making. It was necessary for participants to read the sentences throughout the experiment, but no processing was needed at the point of image presentation for tasks such as reading or speech production. At the point of testing, the participant is thought to have built up a mental representation of the sentence structure, which gives the participant the ability to differentially activate elements that were previously presented in the sentence. This design was used to carefully control the available information and the skills necessary to complete the task across experimental conditions.

Another factor that was taken into account while designing these experiments was mode of delivery. Previous research has often used auditory presentation of sentence stimuli and visual presentation of the word strings being primed (cross-modal technique). It is possible that different modes of delivery affect the processing of a sentence. Visual presentation of both sentence and image stimuli in this experiment was done to keep the mode of delivery constant. It was also done to promote continual attention throughout the entirety of the testing period.

3.2 Pilot Study

As stated in the previous section, this experiment was designed as a reaction time experiment using a visual priming paradigm. It is a pilot study completed in order to test for effects of PRO reactivation at varying points within control sentences. This experiment was designed in Norwegian and 22 native speakers of Norwegian were tested as participants. The testing period was approximately 20 minutes per participant.

3.2.1 Sentence Stimuli

The experiment had a total of 12 sentences used during testing. Eight of these were sentences containing PRO, four object control and four subject control, and the other four were filler sentences with unrelated structures that did not contain PRO. Each sentence was presented with different priming and image conditions. They were presented so that an equal number of 'yes' and 'no' answers were expected. Each sentence contained a different verb and two animal noun phrases. The verbs were selected so that they would be followed directly by an NP and then the infinitive marker *å*, and so that there was no grammatical need for the words *til* or *om* before the infinitive marker. This was done to eliminate the possibility of *til* or *om* signaling advanced referent reactivation. Examples of each sentence type are given in (1) and (2) below. To see the full list of sentences used, see Appendix A.

(1) Test sentences:

a. Object control:
Flodhesten frarådet alligatoren_i PRO_i å gå til festen.
The hippopotamus warned the alligator to go to the party.

b. Subject control:
Alligatoren_k lovet sjiraffen PRO_k å bade i sjøen snart.
The alligator promised the giraffe to bathe in the sea soon.

(2) Filler sentence example:

a. Flodhesten gikk med elefanten til konserten i går.
The hippopotamus went with elephant to the concert yesterday.

There were also four training sentences with unrelated structures (not containing PRO) that were used before the test sentences began to appear. An example of these training sentences is shown in (3) below. These sentences had two test positions and appeared two times each. In order to train the participant, these training sentences would repeat if they were answered incorrectly. The participant also received written feedback on the correctness of their answer. This was done so that the participant was familiar with the task and could produce data with good task compliance.

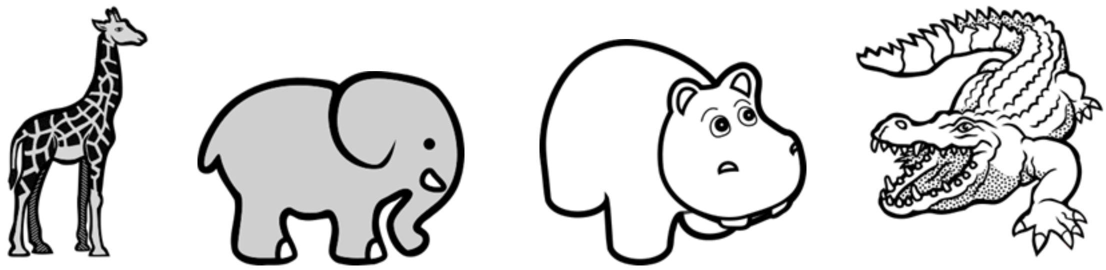
(3) Training sentence example:

a. Flodhesten sprutet på alligatoren med vann fra innsjøen.
The hippopotamus squirted the alligator with water from the lake.

3.2.2 Image Stimuli

The animals selected for the experiment were alligator, hippopotamus, giraffe, and elephant. These were chosen because they all inhabit the same category of common African animals and because they are all approximately the same word length in Norwegian. The images used for these animals are shown in (4) below. The PRO sentences were made to contain no other anaphoric items that might cause trace confusion or interaction.

(4) Image stimuli



3.2.3 Test Positions

In each test and filler sentence, three positions were tested for antecedent reactivation and priming. The first position, located before the infinitive, is where PRO is positioned in S-structure. It is assumed that referent reactivation would take place in this position because this position would show priming if immediate reactivation were to occur while processing a sentence. The second position tested, located after the infinitive, is where PRO is positioned in D-structure. The final position tested is located at the end of the sentence to test for the possibility of delayed reactivation. Each animal image was displayed once in each of the three positions for all 12 sentences. One of the example test sentences presented previously is shown again in (5) with the three test positions indicated by an asterisk. This made for a total of 144 sentence/image combinations per participant, excluding training sentences.

(5) Flodhesten frarådet alligatoren_i PRO_i * å * gå til festen *.
The hippopotamus warned the alligator * to * go to the party *.

3.2.4 Experimental Equipment

For the experiment, a participant was sat in front of a computer located in a soundproof room with a response box similar to the one pictured in Figure 3.1. Directions were presented in Norwegian and the participant pressed any button to begin. The participant began with training sentences and then gradually progressed to the test and filler sentences. The sentences were presented one by one in a different randomized order for each participant. Each word appeared individually on screen for 500 ms/word and then disappeared before the next word was displayed on screen. This paced-reading strategy was used to keep the participant alert and to maintain a realistic reading pace.

Figure 3.1: Cedrus RB-540 Response Box

Throughout this process, an image was shown in one of the three test positions of a sentence each time that it was presented. The participant was asked to determine whether or not the animal in the image had been mentioned previously in the sentence. The image was only shown on screen for a maximum of 3000ms or until a participant response was recorded. This forced the participant to answer as quickly as possible by pressing a green button for ‘yes’ and a red button for ‘no’.

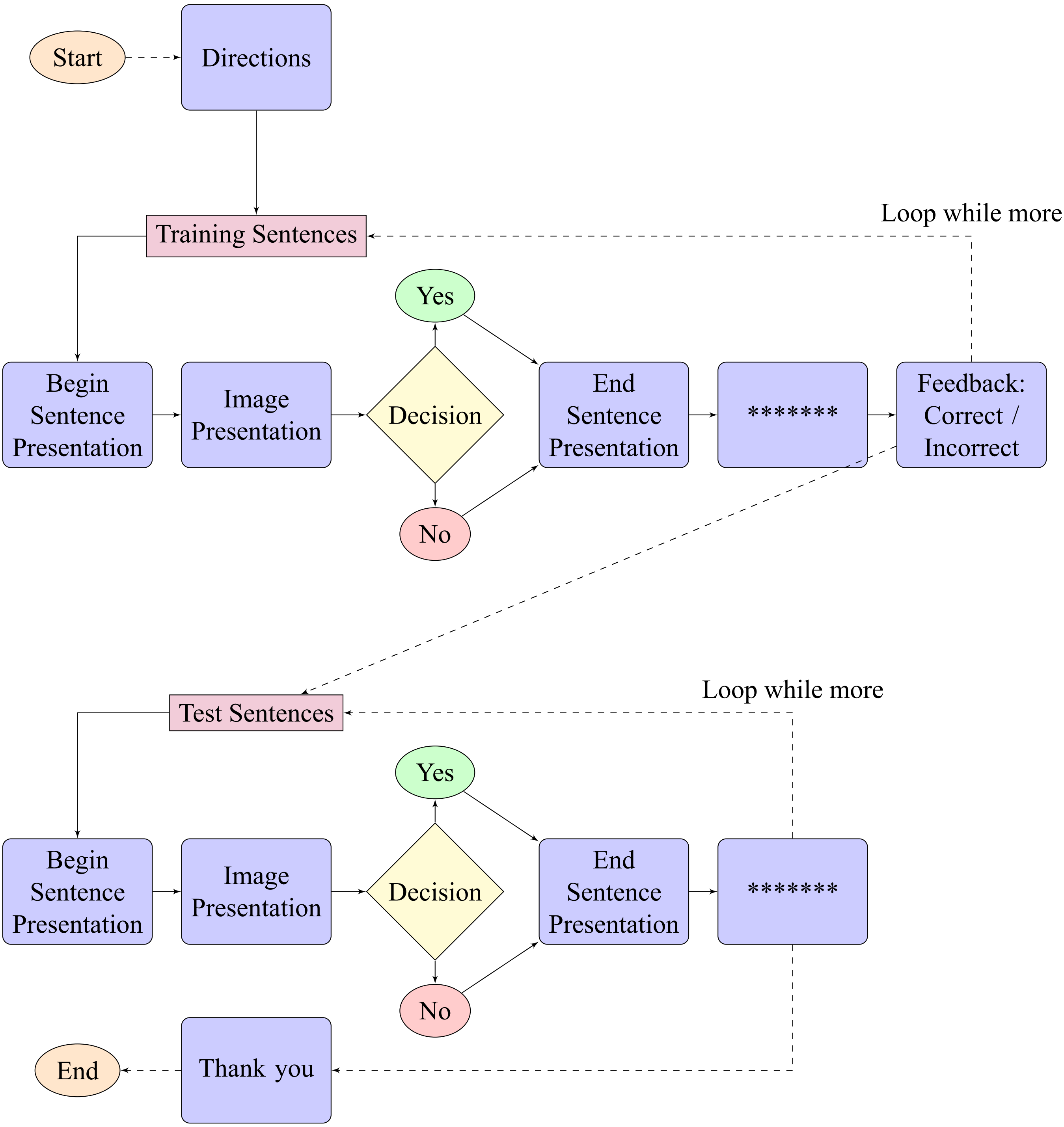
The green button was located on the right hand side and the red button was located on the left hand side. This made it easier for the participant to separate the two buttons, as they were opposite colors and located on opposite sides. A line of asterisks was displayed between each sentence to give the participant complete closure before the next sentence began to appear. A flowchart of the timeline of the experiment has been provided in Figure 3.2.

The programming was completed using Superlab5, which enabled the 144 sentences to be presented in a different randomized order for each participant. This was done to cancel out any possible learning and repetition effects that could transpire from the use of the same sentences and images multiple times throughout the experiment. As another precaution to prevent biases towards a certain answer or pattern, an equal number of correct ‘yes’ and ‘no’ answers were assured for each participant as well as an equal number of occurrences of each animal image.

3.2.5 Summary

The results of this experiment provided a good basis for further study. The number of factors and test points within such a small study made it difficult to pinpoint significant effects. The effects found led to a larger study. This experiment showed that confusion between the hippopotamus and elephant images was common and so the hippopotamus was replaced in the later study. The length of the experiment was another concern. Some participants showed signs of fatigue after twenty minutes of testing. The following experiment was shortened in order to improve the quality of the recorded data.

Figure 3.2: Timeline of events:



3.3 Main Experiment

As a continuation of the previously described pilot study, the main experiment discussed in this section was designed in a similar manner. This experiment was extended to include raising sentences as well as control sentences in order to test the theoretical and processing differences between the two similar construction types. The focus was to test for the reactivation of the antecedent of PRO in control structures and the reactivation of the referent of the raising trace in raising structures. These reactivations were compared in the position that they occurred, if they occurred. This experiment was also completed in Norwegian and 64 native speakers of Norwegian participated. The testing period was approximately 15 minutes per participant.

3.3.1 Sentence Stimuli

The experiment had a total of 20 sentences used during testing. These sentences included four sentences of each of the following categories: subject control (two possible controllers), subject control (one possible controller), object control, subject-to-subject raising (one possible referent), and subject-to-object raising. Each sentence contained different control or raising verbs and was presented a total of four times throughout the experiment. The verbs were again selected so that they would be followed directly by an NP and then the infinitive marker *å*, and so that there was no grammatical need for the words *til* or *om* before the infinitive marker. Examples of each test sentence type are provided below in (6). To see the complete list of sentences used in this experiment, see Appendix A.

(6) Test sentence types:

a. Subject control (two possible controllers):
Apekatten$_i$ lover elefanten PRO$_i$ å bade i sjøen snart.
The monkey promises the elephant to bathe in the sea soon.

b. Subject control (one possible controller):
Apekatten$_j$ lærer PRO$_j$ å sprute vann ut av nesen.
The monkey learns to squirt water out of the nose.

c. Object control:
Elefanten tillater sjiraffen$_k$ PRO$_k$ å plukke blomster i hagen.
The elephant allows the giraffe to pick flowers in the garden.

d. Subject-to-subject raising:
Alligatoren$_m$ synes t$_m$ å fange fisk til frokost hver dag.
The alligator seems to catch fish for breakfast everyday.

e. Subject-to-object raising:
Bananen$_n$ antar apekatten t$_n$ å være god til middag.
The banana, assumes the monkey to be good for dinner.

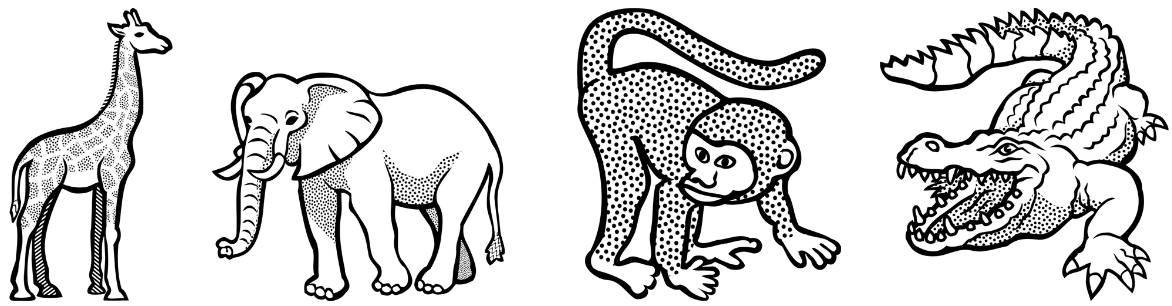
This experiment made use of training sentences in the same way as the pilot experiment. There were 12 total training sentences with random sentence structures (not containing PRO or raising traces). As in the pilot experiment, these sentences were presented at the beginning of the experiment to help train participants to associate the NPs with their correct image equivalent. They were also included to ensure a good participant understanding of the task at hand and, as a result, good task compliance.

3.3.2 Image Stimuli

The animal NPs and images were selected to remain in the same common African animal category that was previously utilized; however, as stated in the end of the last section of the pilot study, one of the animal images was replaced. In this experiment, alligator, giraffe, and elephant were used once again, but hippopotamus was replaced with monkey in order to reduce the confusion that occurred in the pilot study between elephant and hippopotamus. The monkey was chosen because it has a similar word length in Norwegian compared to the other animal NPs.

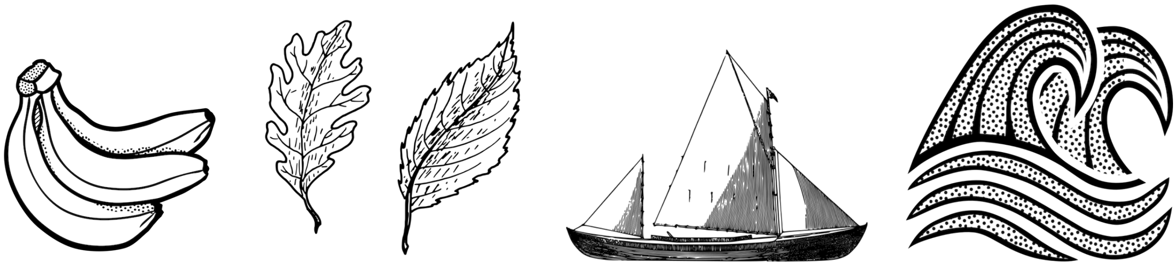
All test images were thus from the same semantic field, with similar word length in letters and similar word frequencies. The images were presented in all experimental conditions to prevent the possibility of association between image and response type or condition. The test sentences were made to contain no other anaphoric items that might cause trace confusion or interaction. The images used in the main experiment are included below in (7).

(7) Animal image stimuli



This experiment included four other image stimuli as well, due to the unique constraints that Norwegian grammar imposes on raising sentences. The effects of the Direct Object Constraint are discussed in Chapter 2. These sentence constructions also have animacy requirements. In order to construct grammatically correct and acceptable raising test sentences, it was necessary to include inanimate NPs and image stimuli to accompany them. These images are shown in (8).

(8) Inanimate image stimuli



3.3.3 Test Positions

Based on the results of the pilot study, this experiment narrowed the testing focus of PRO antecedent and trace referent reactivation to two positions in the sentences. The selected positions had previously shown larger and more consistent effects in the pilot study. This was done to decrease factor size to allow the data to better account for the experimental variance. It was also done to decrease the duration of the experiment so that participants would show less effects of fatigue compared to the longer pilot study. The two positions used to test priming and reactivation were before the infinitive marker and after the infinitive marker. The reasons for selecting these positions were discussed in section 3.2.3.

3.3.4 Event Presentation

The event timeline of this experiment was the same as that of pilot study. The same equipment was used during this experiment as well. There were, however, differences in the way that images were selected to be shown in the sentences. This main experiment was designed to be larger, yet less strenuous for the participant to complete. A strategy for picture presentation was adopted to keep the experiment to 80 total test sentence presentations, plus training sentences. This drastically shortened the length of the experiment and allowed for more participants to be tested. Participants also showed less signs of fatigue and were more likely to willingly volunteer to participate.

3.3.5 Block Presentation

The strategy used for picture selection required creating two separate blocks of the experiment. The first block presented two of the four possible animal images at both points throughout the test sentences. The second block presented the other two of the four possible animal images at both test points. Only one block was shown per participant. The images selected to be displayed in each sentence were chosen so that an equal number of each animal image was shown per block. Another requirement of the design was to ensure an equal number of 'yes' and 'no' correct answers per block. Each block was tested an equal number of times throughout the entirety of the experiment.

3.3.6 Complications

Using this method of testing required that the subject-to-object raising sentences be treated in a special manner. Since these construction types demand the use of inanimate NPs, the inanimate images were reserved for these sentences. Each image was again presented an equal number of times and the selection of images per block was done in the same way as for the animal images. As a consequence, the inanimate images occurred less frequently throughout the experiment. These images were only used in the StO raising analysis.

3.4 Data Validity and Other Considerations

Some of the main reasons for using reaction time experiments that involve a priming paradigm were presented at the beginning of this chapter. There are also general advantages for the use of these research techniques. Reaction time experiments can be completed in a short period of time and do not require the use of advanced and expensive equipment. The participants can partake in the experiment without prior training or an extensive setup of equipment. This helps to ensure that the process is the same for all participants.

In relation to experimental work on the gap-filling process (Nicol and Swinney, 1989) in which a moved constituent is linked to its trace, there has been sufficient evidence of referent reactivation and consequent priming of reaction times for semantically related stimuli (Nicol and Osterhout, 1988; Osterhout and Nicol, 1988; Walenski, 2002; Hestvik et al., 2005). A similar outcome was found when presenting image stimuli in gap positions (Hestvik et al., 2010). Therefore, the validity of the hypotheses and inferences drawn from the data of this experiment has a basis in previous experimental work.

3.4.1 Priming

The priming that takes place in these experiments stems from the PRO or trace that is postulated to fill a specific test position in the sentence. This is semantic priming occurring at the syntactic position of these items. The activation of the PRO or raising trace should facilitate the decision if the presented image is the correct referent. One thing to consider when measuring priming effects is the possibility that this effect lingers slightly while processing continues (Nicol and Swinney, 1989). Since two of the positions tested in these experiments are close in linear distance, it is possible that a small effect of priming may continue from position one, before the infinitive marker, to position two, after the infinitive marker. In the pilot study, semantic priming found in the third position might also be found due to items in the subordinate clause that are associated with the antecedent of PRO. The data analysis will consider minimal comparisons, where ideally only one factor is changed between comparisons.

The reliability of response priming experiments has been proven over time in a variety of experimental work (Klotz and Neumann, 1999; Klotz and Wolff, 1995; Vorberg et al., 2003). Priming effects are generally larger and more noticeable than effects found using other experimental techniques. They can account for 25 percent or more of the overall response time of a participant. The results of priming are typically found to be stable across participants and so a relatively small sample size can be used without compromising the accuracy of the results (Schmidt et al., 2011).

The type of priming stimuli utilized in the experimental work presented in this thesis is unique in the way we consider the stimulus-onset asynchronies (SOAs). Priming effects can differ based on prime-target SOA and the greatest effects are usually found with SOAs shorter than 100ms (Schmidt et al., 2011). Considering the priming effect is based on syntactic position, rather than direct proximity, SOA becomes more or less irrelevant. The exposure time of each word is more relevant and was kept at a constant rate of 500ms per word.

Age was not explicitly controlled during the selection of participants, as the age span was small in the population available. The majority of the participants were students conveniently selected from the University of Bergen's campus area. Participants were also recruited on Facebook and through other personal networks. The participants were told that it was a linguistic experiment but were not told any details prior to the beginning of the experiment. It is possible that the sample of individuals is not representative of the whole population of native Norwegian speakers.

3.5 Data Analysis

3.5.1 Data Preparation

The data recorded in SuperLab5 was saved in separate text files and labeled by participant number. No personal information was recorded so that the collected data was anonymous and could not be traced back to individual participants. Two participants were removed from the pilot study due to low task compliance. Two participants were also removed from the main study, one did not finish the experiment and the other did not understand the task. The remaining files were then imported into Cedrus Data Viewer and combined into one tab delimited text file per experiment. Some data cleaning and preparation was necessary before statistical analysis began and this was completed using Microsoft Excel.

In Excel, excess file headings and non-essential information was deleted from the data file. This included date and software information. Each data file column name was simplified for ease of use while doing the analysis. The data collected from training sentence presentations was deleted from the data file and extra tags were added in addition to those programmed to be included in SuperLab5. The priming type had to be manually tagged in both studies and the position number had to be changed from a numerical value to the literal word form of that value. The test positions were tagged manually in the pilot study.

The final data file included the block number, participant number, image presented, participant response, correct response, RT, condition, position, verb, and priming type. Further subsetting of data will be discussed in the following section as well as the results chapter of this thesis.

3.5.2 Statistical Analysis

The statistical analysis of both the pilot and main experiment was completed in RStudio (RStudio Team, 2015). The lmerTest (Kuznetsova et al., 2016) and lattice packages (Sarkar, 2008) were used during various steps of the analysis. This section will introduce the methods and techniques used during the analysis. A more extensive discussion will take place in Chapter 5, which includes the experimental results.

Pilot Study

The pilot study data file included data recorded from twenty participants. The first part of the analysis was done using the subset function in RStudio to clean the data further. The final version of the data to undergo analysis was comprised of correct participant responses and correctly primed test data.

To investigate the distribution of the dataset, a histogram was created to visualize the overall distribution of RT values. The RT was subsetted to include only values between 400 and 1800ms. Then an outlier analysis was done for verbs, participants, and images. Though no verbs or participants were excluded at this point due to their effect on the data, understanding the effects of these factors helped to decide the random factors to be included in the statistical model of the experiment.

The statistical modeling was done using the *lmer* function of the lmerTest package. The use of lmer mixed effects modeling allowed for the fixed and random factors of the experiment to be accounted for and for the calculation of the individual effects of the sublevels of these factors. Fixed factors are measures that are repeatable and have a limited number of levels. Most importantly, all relevant levels are present in the data.

Random factors are sampled randomly from a larger category or population and they control the variance of the data (Baayen, 2008). Therefore, not all levels are present in the data. For example, I could have selected different verbs, images, and participants to use for the experiments. As a consequence, variance due to such factors is calculated with more caution within the models. It is important to consider both factor types during analysis and this is possible using mix effects models, as the variance of random effects can be estimated. The factors used in creating the final lmer model for the statistical analysis of the pilot study data are shown in (9).

(9) a. Fixed factors:

•**Condition (PRO)**
- Control: Subject, Object

•**Position**
- One: Before the infinitive marker
- Two: After the infinitive marker
- Three: At the end of the sentence

•**Priming**
- Syntactic: The image is coreferent with PRO or the raising trace. The expected answer is 'yes'.
- Non-syntactic: The image is not coreferent with PRO or the raising trace. The expected answer is 'yes'.
- No priming: The image is unrelated to the sentence. The expected answer is 'no'.

b. Random factors:

•**Participant**

•**Image**

•**Verb**

The broader significance of these effects were calculated by using the *anova* function. Testing the quality of the model and its goodness of fit in relation to the dataset, a *qqplot* was created and the values of the degrees of freedom for factors included within the model were checked for appropriateness. I analyzed the data with and without the effects of passive constructions. This overall pilot analysis inspired the creation and specific design of the main experiment.

Main Experiment

The main experiment data file included data recorded from sixty-two participants. The data was cleaned even further using the subset function in RStudio. The final version of the data to undergo analysis was comprised of only correct participant responses.

First and foremost, a histogram was created to understand RT data distribution. The data was then subsetted to include only RT values between 400 and 1800ms. The dataset became more normally distributed and the responses that were too quick to be anything other than a reflex to press a button were removed. An outlier analysis was completed for verbs, participants, and images. None were excluded due to being extreme outliers, but these factors were later included as random factors in the statistical model.

Lmer mixed effects models were used to better account for the variance attributed to both fixed and random effects. In the beginning model, block number was included as a fixed factor together with condition, position, and priming type. However, when compared to the same model without the block factor, there was found to be little to no effect for block. The block factor was ultimately omitted of the final model because of this and to reduce the number of factors that the model must account for, along with model complexity. The final random and fixed factors are listed in (10).

(10) a. Fixed factors:

- **Condition**
  - Control: Subject (1 possible antecedent), Subject (2 possible antecedents), Object
  - Raising: Subject-to-subject, Subject-to-object
- **Position**
  - One: Before the infinitive marker
  - Two: After the infinitive marker
- **Priming**
  - Syntactic: The image is coreferent with PRO or the raising trace. The expected answer is ’yes’.
  - Non-syntactic: The image is not coreferent with PRO or the raising trace. The expected answer is ’yes’.
  - No priming: The image is unrelated to the sentence. The expected answer is ’no’.

b. Random factors:

- **Participant**
- **Image**
- **Verb**

To allow the model to have the greatest power in estimating effects, the control and raising data was analyzed together and then separately. These models were found to be best for the data after comparing the system’s ability to process the models and also the degrees of freedom produced by the models.

The *anova* function was again used as a way to assess the significance of the fixed factors in the experiment. Interaction plots for various levels of each factor were created to illustrate the role of position and priming in relation to condition. Post-hoc analysis included comparing factor effects when including or eliminating the passive test sentences in the dataset.

Chapter 4

Data and Results

This chapter includes the results of both the pilot study and the main experiment. The pilot study displayed significant effects of priming, priming and control type, and an interaction between control type, priming type, and test position. Linear mixed effects models were used to conduct pairwise comparisons of test positions and to estimate factor and interaction effects. Interaction plots illustrated a speedup effect (~32-45ms, depending on passive sentence exclusion) of position two in comparison to position one when subject control constructions were syntactically primed. A similar effect was found for position three under the same conditions in comparison to position one (~50ms). When primed syntactically in position one, object control sentences displayed a large speedup in RT compared to position two (~73ms) and three (~69ms). The results also showed an effect of passive constructions on the processing of control.

When considering exclusively the effects of position on control sentence types when primed syntactically, position two exhibited a mean RT almost 30ms faster than that of position three for subject control. Position one and two showed similar effects for subject control until passive constructions were excluded, and then position two was approximately 13ms faster. Position one continued to display the fastest mean RT for object control.

The main experiment showed significant effects across condition, providing support for processing differences between control and raising sentence structures. Greater priming effects were recorded, with both syntactic and non-syntactic priming effects showing significance. The results showed a large effect for subject control sentences when syntactically primed in position two (~35-60ms, depending on passive sentence exclusion). A small effect of approximately 10ms is found for object control sentences under the same conditions. Position does not display as large of an effect in raising sentence constructions; nevertheless, there is a general trend of a faster mean RT for syntactically primed raising sentences in position one. This is the opposite trend of that found for control sentences. Passive constructions were found once again to effect the processing of control.

The data presented in this chapter was recorded using the methods described in the previous chapter. First, the results from the pilot study will be discussed and then the main experiment will follow. This section will include the model presentations for each dataset and a discussion of effects and significant factor interactions.

4.1 Results of Pilot Study

Section 4.5.1 laid out the steps taken to clean and prepare the data for analysis. The final file included 2,880 data points, but afterwards 169 were excluded due to incorrect responses and 3 were excluded due to no responses, resulting from time out at 3000ms. The original statistical analysis was completed in collaboration with my supervisor, Christer Johansson, and was presented in a poster at the annual Psycholinguistics in Flanders (PIF) conference (Larsen and Johansson, 2016b) and in a talk at the Forty Years After Keenan 1976 conference (Larsen and Johansson, 2016a).

The original formatting of the Excel data files was done by a group of students and did not include labels on priming type, only whether or not image priming was done using an NP from the matrix clause. The design of the experiment included these contrasts in priming type, but they were not programmed as tags in Superlab5 when the experiment first took place. The data was relabeled manually and the results of the analysis of the data including priming data tags will be presented in this thesis.

4.1.1 Outlier Effects

The following presentation of the results will be completed using information from an outlier analysis that I did prior to this analysis. For a complete overview of the outlier analysis, see Chapter 5. We will begin by considering the mixed effects models created to analyze the effects of fixed factors within the experiment. I found an outlier participant that could possibly drive effects in the data. In order to explore this possibility, two versions of the same lmer model were created in RStudio using the *lmerTest* package. Analyzing the dataset with and without the outlier participant enabled me to calculate the difference in effects caused by the inclusion of this participant (P6).

The first version of the model contained all data points included thus far. The second version of the model contained all data points except those produced by the participant labeled P6. The model equation used to estimate effects is included below in (1). The model was selected to explain the most variance, while still holding to a complexity level appropriate for the dataset. It is important to consider the size of the dataset when selecting an equation for a mixed effects model.

(1) model1 <-lmer(RT~PRO * Position * Priming + (PRO| Participant) + (Priming | Verb) + (1 | Image))

The number of factors that we can use as slopes for the random factors is limited by the amount of data. If a slope is specified using the notation of (slope|factor), then an estimate for the effect associated with each specified level of the factor is added to the model. For example, in the equation in (1), I used (PRO|Participant). This shows that the type of control was used as the slope for participant, as indicated by the vertical bar in the equation.

I chose this slope because it is possible that each participant reacts differently to the subtypes of control. Using this slope, the effects for each participant are calculated separately for each level of PRO. In addition, each participant will have their own intercept (starting point). This means that participants with overall slower or faster RTs will have the same chance of effecting the results. This is also the case for individual verbs, where the slope is estimated using priming type. It is possible that each verb is affected differently by priming due to verb frequency or the underlying verb structure and characteristics.

Only an intercept is used for image, as represented by (1 | Image). This intercept provides a baseline mean or and starting point that changes from one factor level to another and makes by-image adjustments by using small changes in the intercept (Baayen, 2008). A slope allows us the possibility to estimate different expectations for different levels of a factor. I chose to only use an intercept for image because I assume there is little difference in effect across the levels of this factor.

Random effects in general are included in a model to track the sources of variance, helping the model to identify sources of reliable differences in the dataset. The addition of random factors with slopes mainly affects how much variance can be accounted for and, thus, the within-degrees of freedom. I chose to use random effects models for my statistical analysis because they are more conservative and are less likely to underestimate variance. This makes the models more cautious when pinpointing and estimating significant effects.

The effects calculated in each model were compared to gain a better understanding of the effect that participant P6 had on the experimental results. The calculations and effects estimated in model1 (containing P6) and model2 (excluding P6) display differences in effect size but not in the general existence of effects. Certain effect sizes in model2 grew such as the interaction effect between syntactic priming and object control (+18.17ms) and the interaction effect between syntactic priming, object control, and position two (+19.90ms). Other effect sizes decreased like that of the interaction effect between syntactic priming, object control, and position three (-4.21ms) and the interaction effect between non-syntactic priming, subject control, and position three (-21.75ms). The change in effect sizes mentioned here are those that led to a shift in significance.

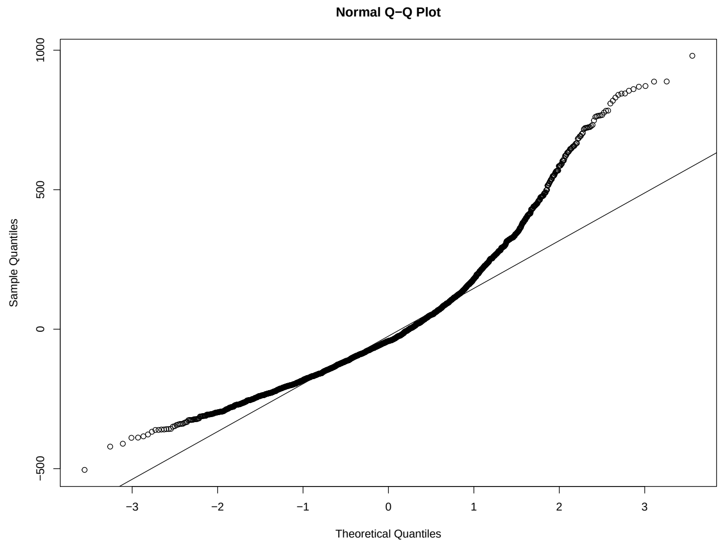
Using a One-sample Kolmogorov-Smirnov test, I found that the residuals of the model of the complete dataset has a smaller D-value ($D = 0.0997$, p-value $< 2.2e-16$) than that of the residuals of the dataset that excludes participant P6 ($D = 0.105$, p-value $< 2.2e-16$). Therefore, the residuals of the complete dataset tend more towards a normal distribution when compared those of the dataset without P6. When the residuals of the two models are tested against each other using a Two-sample Kolmogorov-Smirnov test, we get a very small but significant difference ($D = 0.064$, p-value $= 3.345e-05$).

I will continue the data analysis with P6 included in the dataset; however, it is worth mentioning that the mean RT of P6 is 1092.68ms and that of the overall dataset is 807.94ms. The possibility that P6 shifts some effects must be kept in mind. We will keep P6 because using a mixed effects model helps to account for individual variance between participants by using specific slopes for random factors (Baayen, 2008) and we have already shaved off the extreme low and high outlier RT data. There is not enough evidence that P6 solved the task in a qualitatively different manner; therefore, it is possible that P6 simply took longer to make decisions.

In Figure 4.1, a graph is shown of a linear function following the model created to represent the data in comparison to a quantile-quantile plot of the dataset itself. The two first quantiles are accurately represented by the model and this representation continues to be relatively accurate until the end of the second quantiles.

There are outliers on both the low and high ends of the graph, but we cannot expect a perfect normally distributed dataset when it comes to experimental work. As stated previously, it is possible these high and low values are due to factors unrelated to the experiment.

Figure 4.1: QQ plot of Mixed Effects Model Compared to a Normally Distributed Model Fit



If this is the case, it is reasonable to assume that the model will not be capable of explaining these outlier RTs. The low RT values can be from an automatic reflex to press a button when an image is presented on screen. The participant requires a certain amount of milliseconds to process the image, to make a decision, and finally to send a signal from their brain to their finger that says which button should be pressed. That means that some extremely low RT values could be responses given before the participant has fully processed the image on screen. The high could be from fatigue or the need to scratch an itch. Even so, it is similarly possible that these values are due to the complexity of the syntactic phenomena being tested and are important points in the dataset.

So far, the data presented has included all of the verbs used in the original pilot experiment. After a second look at the test sentences, I noted that one of the subject control verbs used forced the test sentences to be in passive form. The sentence is shown in (2), where the subject of the sentence, *Sjiraffen*, is being acted upon instead of being the actor itself. When a sentence is passivized, the object of an active sentence becomes the functional subject of the passive sentence. This could cause the sentence to be processed in a different manner. The boxplot of RTs per verb did not show any verbs diverging from the rest; however, considering the underlying structure of passive sentences, it is necessary to consider the possibility that these passive sentences had an effect on the data.

(2) Sjiraffen$_i$ lærte av elefanten PRO$_i$ å drikke fra elva.
The giraffe learned from the elephant to drink from the river.

One interesting characteristic of verbs such as *lærte* in Norwegian is that they can have two different meanings depending on context and sentence structure. Consider (3) below. The removal of the preposition *av* changed the semantics of the matrix clause verb and the type of control occurring in the sentence, causing a change in PRO antecedent. In English, as we can see from the translations, two different matrix clause verbs must be used. It is possible that this property of certain verbs in Norwegian affects the reader/listener's predictions when processing a sentence.

(3) Sjiraffen lærte elefanten$_j$ PRO$_j$ å drikke fra elva.
The giraffe taught the elephant to drink from the river.

4.1.2 Mixed Effects Pairwise Factor Analysis

In order to estimate effects for all levels of each factor, the data was subsetted to include two levels of each factor in separate datasets. Creating a model that compared all factor levels at once did not accurately compute and left out significant effects, such as syntactic priming. I solved this issue by limiting each model to pairwise level comparisons (subject and object control, syntactic and non-syntactic priming, position one and two/position two and three/ position one and three). These models include estimated effects for the fixed factors as well as the variance stemming from the random factors. We will focus on the fixed factors.

Below in Table 4.1 to Table 4.6 are the summaries of all six mixed effects models. Table 4.1, 4.3, and 4.5 include data from the passive test sentences. Table 4.2, 4.4, and 4.6 exclude passive constructions. The model used for each analysis is shown above the table. The values in the table are all rounded to the hundredths place. The factors or interactions of factors that show significance are marked by an asterisk or a bullet next to the p-value.

Table 4.1: Data including Subject and Object Control in Position One and Two, Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom ['lmer-Mod'] Formula: RT ~PRO * Position * Priming + (PRO + Position + Priming | Participant) + (1 | Verb) + (1 | Image)

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	838.77	42.77	30.34	19.61	***0.00
Subject	-99.46	40.72	32.44	-2.44	*0.02
Positiontwo	-25.25	33.29	415.46	-0.76	0.45
Syntactic	-127.67	34.63	339.60	-3.69	***0.00
Subject	58.09	46.42	539.44	1.25	0.21
Subject:Syntactic	201.54	47.01	540.89	4.29	***0.00
Positiontwo:Syntactic	98.54	46.30	539.56	2.13	*0.03
Subject:Positiontwo:Syntactic	-163.10	65.87	540.79	-2.48	*0.01

The type III Analysis of Variance with Satterthwaite approximations for the model in Table 4.1 showed significant effects for the interaction between control type and priming ($F(1, 540.40) = 13.25$, $p < 0.0003$***) and control type, position, and priming ($F(1, 541.71) = 6.13$, $p < 0.014$*). This was calculated using the *anova* function included in the *lmerTest* package in RStudio. I calculated the significant effects using the estimates in Table 4.1. The intercept is object control, position one, and non-syntactic priming. To calculate the other effects, the estimated difference in effect for each factor level must be added or subtracted from the intercept. This is shown below in (4).

(4) Object control, syntactic priming: 838.77 - 127.67 = 711.1
Object, non-syntactic priming: 838.77
Subject control, syntactic: 838.77 - 99.46 - 127.67 + 201.54 = 813.18
Subject, non-syntactic: 838.77 - 99.46 = 739.31
Object, position one, syntactic: 838.77 - 127.67 = 711.1

Object, position two, syntactic: 838.77 - 25.25 - 127.67 + 98.54 = 784.39
Object, position one, non-syntactic: 838.77
Object, position two, non-syntactic: 838.77 - 25.25 = 813.52
Subject, position one, syntactic: 838.77 - 99.46 - 127.67 + 201.54 = 813.18
Subject, position two, syntactic: 838.77 - 99.46 - 25.25 - 127.67 + 58.09 + 201.54 + 98.54 - 163.10 = 781.46
Subject, position one, non-syntactic: 838.77 - 99.46 = 739.31
Subject, position two, non-syntactic: 838.77 - 99.46 - 25.25 + 58.09 = 772.15

Table 4.2: Data including Subject and Object Control in Position One and Two (Excluding Passives), Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom ['lmerMod'] Formula: RT ~PRO * Position * Priming+ (PRO + Position | Participant) + (1 | Verb) + (1 | Image)

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	836.49	43.62	29.80	19.18	***0.00
Subject	-91.12	46.22	24.00	-1.97	•0.06
Positiontwo	-25.50	33.91	178.24	-0.75	0.45
Syntactic	-125.63	34.90	250.56	-3.60	***0.00
Subject:Positiontwo	52.57	50.41	473.53	1.04	0.30
Subject:Syntactic	194.97	51.76	471.99	3.77	***0.00
Positiontwo:Syntactic	98.87	46.70	473.70	2.12	*0.03
Subject:Positiontwo:Syntactic	-170.79	71.72	474.05	-2.38	*0.02

The type III ANOVA with Satterthwaite approximations for the model in Table 4.2 showed significant effects for the interaction between control type and priming ($F(1, 453.65) = 9.01$, $p < 0.002$**) and control type, position, and priming ($F(1, 475.90) = 5.67$, $p < 0.018$*). I calculated the significant effects in (5) using the estimates in Table 4.2. The intercept is object control, position one, and non-syntactic priming.

(5) Object control, syntactic priming: 836.49 - 125.63 = 710.86
Object, non-syntactic priming: 836.49
Subject control, syntactic: 836.49 - 91.12 - 125.63 + 194.97 = 814.71
Subject, non-syntactic: 836.49 - 91.12 = 745.37
Object, position one, syntactic: 836.49 - 125.63 = 710.86
Object, position two, syntactic: 836.49 - 25.50 - 125.63 + 98.87 = 784.23
Object, postion one, non-syntactic: 836.49
Object, position two, non-syntactic: 836.49 - 25.50 = 810.99
Subject, position one, syntactic: 836.49 - 91.12 - 125.63 + 194.97 = 814.71
Subject, position two, syntactic: 836.49 - 91.12 - 25.50 - 125.63 + 52.57 + 194.97 + 98.87 - 170.79 = 769.86
Subject, position one, non-syntactic: 836.49 - 91.12 = 745.37
Subject, position two, non-syntactic: 836.49 - 91.12 - 25.50 + 52.57 = 772.44

We can see from the effect calculations that the exclusion of passive constructions affected most effects involving subject control. This was expected because the passive sentence in the experiment was from the subject control condition. The largest difference in effect is found in the interaction effect between subject control, position two, and syntactic priming (11.6ms).

Table 4.3: Data including Subject and Object Control in Position Two and Three, Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom ['lmerMod'] Formula: RT ~PRO * Position * Priming + (PRO + Position + Priming | Participant) + (1 | Verb) + (1 | Image)

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	793.60	45.35	30.18	17.50	***0.00
Subject	56.48	45.64	30.95	1.24	0.23
Positiontwo	16.73	36.28	361.92	0.46	0.65
Syntactic	-10.74	36.79	184.11	-0.29	0.77
Subject :Positiontwo	-94.16	51.34	538.19	-1.83	•0.07
Subject:Syntactic	-71.96	51.29	538.16	-1.40	0.16
Positiontwo:Syntactic	-13.83	50.18	534.26	-0.28	0.78
Subject:Positiontwo:Syntactic	108.77	71.51	536.55	1.52	0.13

The type III ANOVA with Satterthwaite approximations for the model in Table 4.3 showed no significant effects. The closest to significant was that of the interaction effect between control type, position, and priming ($F(1, 537.62) = 2.31$, $p < 0.13$). I calculated these effects in (6) using the estimates in Table 4.3. The intercept is object control, position three, and non-syntactic priming.

(6) Object, position three, syntactic: 793.60 - 10.74 = 782.86
Object, position two, syntactic: 793.60 + 16.73 - 10.74 - 13.83 = 785.76
Object, postion three, non-syntactic: 793.60
Object, position two, non-syntactic: 793.60 + 16.73 = 810.33
Subject, position three, syntactic: 793.60 + 56.48 - 10.74 - 71.96 = 767.38
Subject, position two, syntactic: 793.60 + 56.48 + 16.73 - 10.74 - 94.16 - 71.96 - 13.83 + 108.77 = 784.89
Subject, position three, non-syntactic: 793.60 + 56.48 = 850.08
Subject, position two, non-syntactic: 793.60 + 56.48 + 16.73 + - 94.16 = 772.65

The type III Analysis of Variance with Satterthwaite approximations for the model in Table 4.4 showed no significant effects. The closest to showing significance was that of priming ($F(1, 36.82) = 1.66$, $p < 0.21$).

The type III ANOVA with Satterthwaite approximations for the model in Table 4.5 showed effects for priming ($F(1,28.31) = 2.99$, $p < 0.094$•), the interaction between control type and priming ($F(1,531.39) = 3.49$, $p < 0.062$•), and significant effects for the interaction between control type, position, and priming ($F(1,531.43) = 14.90$, $p < 0.0001$***). I calculated the significant effects in (7) using the estimates in Table 4.5. The intercept is object control, position one, and non-syntactic priming.

Table 4.4: Data including Subject and Object Control in Position Two and Three (Excluding Passives), Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom ['lmerMod'] Formula: RT ~PRO * Position * Priming + (PRO + Position + Priming | Participant) + (1 | Verb) + (1 | Image)

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	793.38	47.14	28.04	16.83	***0.00
Subject	43.81	50.46	22.10	0.87	0.39
Positiontwo	16.57	36.74	303.19	0.45	0.65
Syntactic	-10.47	37.21	156.56	-0.28	0.78
Subject:Positiontwo	-74.84	55.44	467.51	-1.35	0.18
Subject:Syntactic	-57.70	55.67	453.22	-1.04	0.30
Positiontwo:Syntactic	-14.19	50.67	465.29	-0.28	0.78
Subject:Positiontwo:Syntactic	77.34	77.61	466.78	1.00	0.32

Table 4.5: Data including Subject and Object Control in Position One and Three, Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom ['lmerMod'] Formula: RT ~PRO * Position * Priming + (PRO + Position + Priming | Participant) + (1 | Verb) + (1 | Image)

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	833.39	41.92	31.28	19.88	***0.00
Subject	-94.76	40.99	33.92	-2.31	*0.03
Positionthree	-38.66	35.55	383.13	-1.09	0.28
Syntactic	-121.57	35.80	207.60	-3.40	***0.00
Subject:Positionthree	148.12	49.83	529.13	2.97	**0.00
Subject:Syntactic	199.15	48.96	530.02	4.07	***0.00
Positionthree:Syntactic	108.45	48.63	528.39	2.23	*0.03
Subject:Positionthree:Syntactic	-268.27	69.49	529.45	-3.86	***0.00

(7) Non-syntactic priming: 833.39
Syntactic priming: 833.39 - 121.57 = 711.82
Object control, syntactic: 833.39 - 121.57 = 711.82
Object, non-syntactic: 833.39
Subject control, syntactic: 833.39 - 94.76 - 121.57 + 199.15 = 816.21
Subject, non-syntactic: 833.39 - 94.76 = 738.63
Object, position one, syntactic: 833.39 - 121.57 = 711.82
Object, position three, syntactic: 833.39 - 38.66 - 121.57 + 108.45 = 781.61
Object, position one, non-syntactic: 833.39
Object, position three, non-syntactic: 833.39 - 38.66 = 794.73
Subject, position one, syntactic: 833.39 - 94.76 - 121.57 + 199.15 = 816.21
Subject, position three, syntactic: 833.39 - 94.76 - 38.66 - 121.57 + 148.12 + 199.15 + 108.45 - 268.27 = 765.85
Subject, position one, non-syntactic: 833.39 - 94.76 = 738.63
Subject, position three, non-syntactic: 833.39 - 94.76 - 38.66 + 148.12 = 848.09

Table 4.6: Data including Subject and Object Control in Position One and Three (Excluding Passives), Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom ['lmerMod'] Formula: RT ~PRO * Position * Priming + (PRO + Position + Priming | Participant) + (1 | Verb) + (1 | Image)

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	833.46	43.29	28.80	19.25	***0.00
Subject	-81.00	44.97	23.86	-1.80	•0.08
Positionthree	-39.00	35.04	361.45	-1.11	0.27
Syntactic	-121.47	36.45	141.24	-3.33	**0.00
Subject:Positionthree	120.79	52.71	461.43	2.29	*0.02
Subject:Syntactic	186.26	52.41	464.02	3.55	***0.00
Positionthree:Syntactic	108.84	48.06	461.44	2.26	*0.02
Subject:Positionthree:Syntactic	-240.62	74.03	463.03	-3.25	**0.00

The type III ANOVA with Satterthwaite approximations for the model in Table 4.6 showed effects for the interaction between control type and priming (F(1,462.60) = 3.17, p < 0.076•) and significant effects for the interaction between control type, position, and priming (F(1,463.03) = 10.56, p < 0.001**). I calculated the significant effects in (8) using the estimates in Table 4.6. The intercept is object control, position one, and non-syntactic priming.

(8) Object control, syntactic: 833.46 - 121.47 = 711.82
Object, non-syntactic: 833.46
Subject control, syntactic: 833.46 - 81.00 - 121.47 + 186.26 = 817.25
Subject, non-syntactic: 833.46 - 81.00 = 752.46
Object, position one, syntactic: 833.46 - 121.47 = 711.99
Object, position three, syntactic: 833.46 - 39.00 - 121.47 + 108.84 = 781.83
Object, postion one, non-syntactic: 833.46
Object, position three, non-syntactic: 833.46 - 39.00 = 794.46
Subject, position one, syntactic: 833.46 - 81.00 - 121.47 + 186.26 = 817.25
Subject, position three, syntactic: 833.46 - 81.00 - 39.00 - 121.47 + 120.79 + 186.26 + 108.84 - 240.62 = 767.26
Subject, position one, non-syntactic: 833.46 - 81.00 = 752.46
Subject, position three, non-syntactic: 833.46 - 81.00 - 39.00 + 120.79 = 834.25

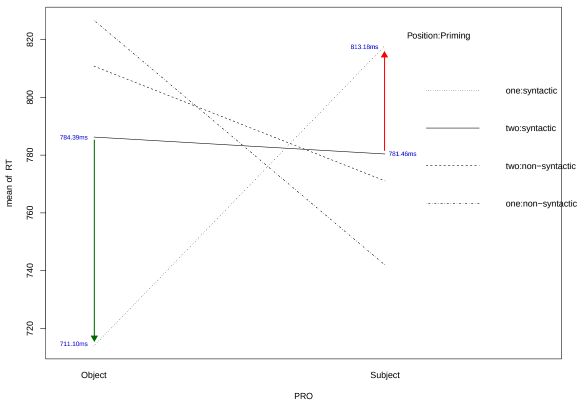
4.1.3 Analysis of Interaction Effects

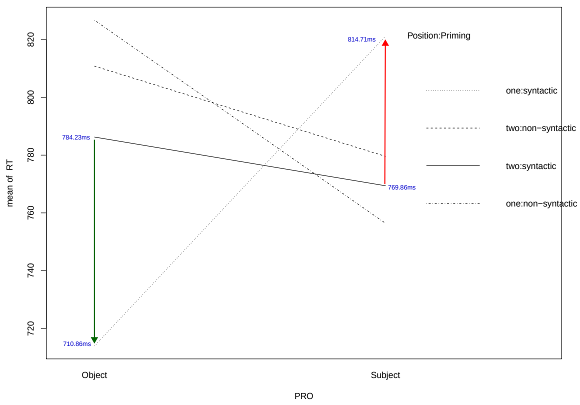
The complete dataset includes a variety of interactions between factors and some of these lead to large shifts in RT. Another way to understand these interactions and compare them across factor levels is to create interaction plots using the *interaction.plot* function in RStudio. In these plots, I have graphed RT on the y-axis and one fixed factor on the x-axis. Then on the right-hand side an interaction of factors are shown in the legend.

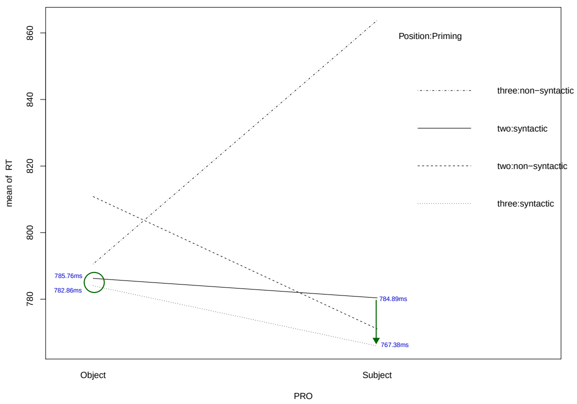
The interaction plots have been combined into a single table (Table 4.7) for the convenience of the reader. The left hand column displays the plots that include the passive sentence constructions and the right hand column contains those excluding passives. The first row of

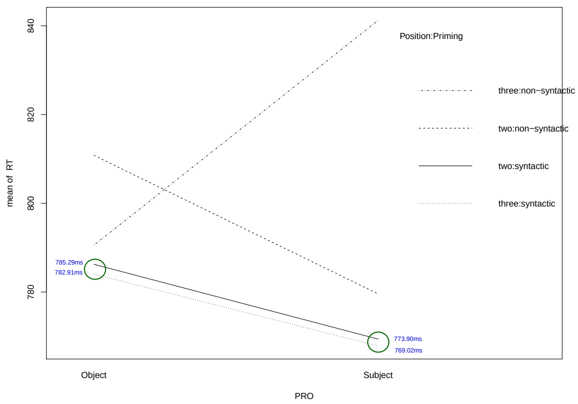
Table 4.7: Interaction Plots Displaying Mean RT Effects of Position and Priming Interaction on Sentence Type, Including and Excluding Passive Constructions

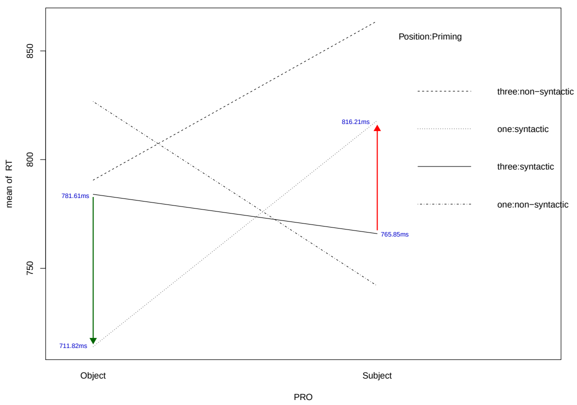
Including Passives	Excluding Passives

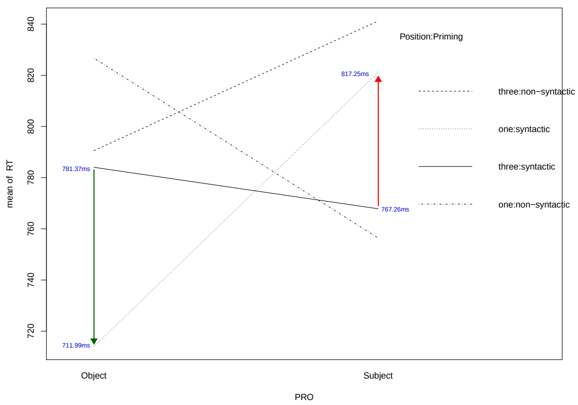












plots compare the interaction effects of priming type and test position one and two on control type. The second row compares the interaction effects of priming type and test position two and three on control type. Finally, the last row compares the interaction effects of priming type and test position one and three on control type. Including all three positions in one plot made it illegible. Keep in mind that some effects cause a shift in the scale of the graph on the y-axis.

I have drawn in the red and green arrows using a PDF editor outside of RStudio in order to highlight the important contrasts. I wanted to use these interaction plots particularly to contrast the effect of position on control type when interacting with priming type. Therefore, the arrows in each plot point out the differences between the two positions included in the plot when syntactic priming was present. The red arrows indicate a slow down and the green arrows indicate a speed up. When the effect was too small to insert an arrow, a circle was used as emphasis.

In the first row of interaction plots, we can see that object control acts in an opposite manner compared to subject control when primed with the correct image of the antecedent of PRO (syntactic priming) in position two. This occurs when syntactically primed in position one as well. These effect sizes are labeled by the arrows in the plot. Subject control shows a mean RT almost 32ms faster for position two compared to position one and object control shows a mean RT approximately 73ms faster in position one than position two. Without the passive test sentences, the interaction effect for cases of subject control and syntactic priming create a larger gap between position one and position two. The plot holds the same general trend, but the decrease in mean RT for subject control and syntactic priming in position two from 32 to 45ms is something to keep in mind.

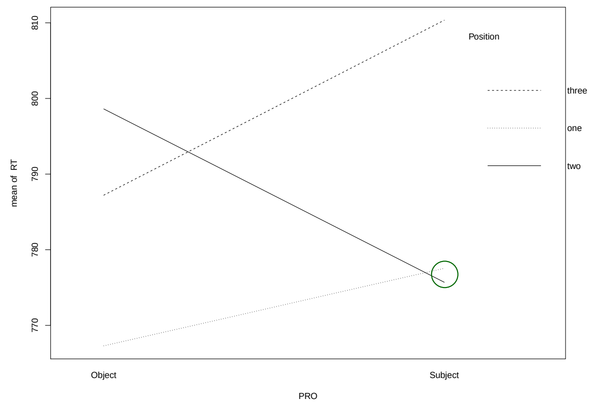
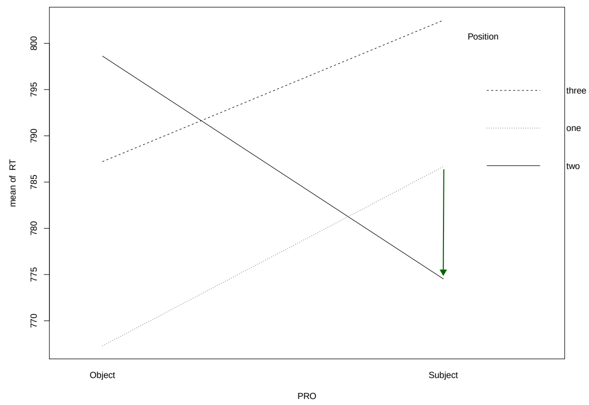
In the second row of interaction plots, we can see that there is a difference in mean RT depending on position when it comes to presentations of subject control sentences and syntactic priming (~18ms faster for position three). This is the case with object control sentences and syntactic priming as well but there is an even smaller effect (3ms). When passive sentence constructions are excluded from the dataset, the previously mentioned differences in RT almost disappear, with a small effect still found for instances of both subject control and syntactic priming (5ms) and object control and syntactic priming (2ms).

Lastly, the final row of interaction plots display data for position one and three. These plots show effect patterns quite similar to those we saw when comparing position one and two in the first row of plots. It is important to keep the scale difference in mind with these plots. The removal of passive constructions does not have much of an effect in this comparison. The largest difference between the two plots is the mean RT for subject control with non-syntactic priming in position three (14ms).

We have noted that subject control sentences presented with syntactic priming in position two lead to a mean RT comparable to that of those in position three under the same conditions. This can be seen again in the similarities found between the plots in row one and three. The removal of passive sentences affects subject control RTs the most, which is expected since the passive sentence was from that condition. The results of the model summary and interaction plots maintain the assumption that passive constructions effect the processing of control.

We will now take one last look at the overall effect of position on control type when primed exclusively syntactically. Table 4.8 shows the mean RT with control type on the x-axis and position shown on the right in the legend. The plot including passive constructions shows position two and three to have a similar effect on subject control sentences. When passives are removed, however, the mean RT of subject control in position three increases and position two remains fastest in that condition. These plots also show that position two and three work in opposite ways for object and subject control.

Table 4.8: Interaction Plots Displaying Mean RT Effects of Position on Sentence Type, Syntactic Priming, Including and Excluding Passive Constructions

Including Passives	Excluding Passives
	

4.2 Results of Main Experiment

The same steps were used while preparing and cleaning the data obtained from the main study for analysis. The data file included 5,952 data points, but 218 were excluded due to incorrect responses and 6 due to no responses (from time out at 3000ms).

4.2.1 Outlier Effects

The results presented in this section were calculated after I conducted an outlier analysis and a data quality check, discussed in Chapter 5. This analysis showed some participant outliers. These participant outliers (P26, P34, P42) will be considered during the statistical analysis in order to examine their ability to drive effects within the data. I will explore two versions of the dataset, one with and one without the most extreme outliers.

Two versions of the same lmer model were created using the *lmerTest* package in RStudio. The model equation is in (9) and is conveniently the same one used for the pilot experiment. This equation was selected for the same reasons as the equation for the pilot experiment. The random factors were given relevant slopes and the model's complexity was limited in relation to the size of the dataset.

(9) model <-lmer(RT~PRO*Position*Priming+(PRO|Participant)+(Priming|Verb)+(1|Image))

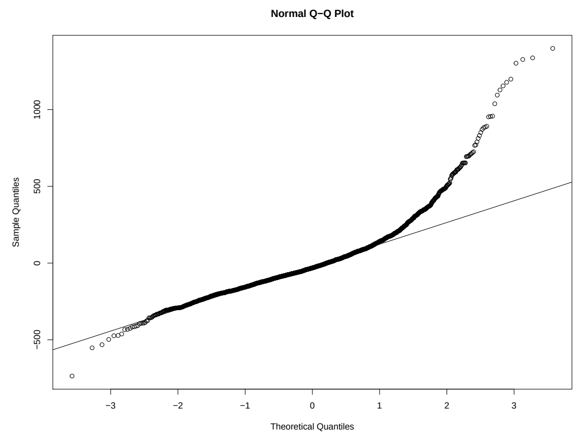
Using the complete dataset, I created a mixed effects model and completed a One-sample Kolmogorov-Smirnov test to test the normality of the model's residuals. The same was done for a dataset excluding participants P26, P34, and P42. The residuals from each model were almost equally close to that of a normal distribution of residuals (D = 0.10252, D = 0.10431, $p < 2.2e\text{-}16$). The residuals of the model using the complete dataset had a slightly smaller D-value, having residuals closer that of a normal distribution. Using a Two-sample Kolmogorov-Smirnov test, I compared the residuals of the two models and got back a small difference in residuals that was not significant (D = 0.00848, p-value = 0.989).

The mean RTs of the three outlier participants (P26: 1169.06ms, P34: 1159.96ms, P42:

1158.59ms) are much greater than that of the complete dataset (793.64ms). Even so, I will continue the analysis using the complete dataset because the model summaries do not show large changes in effect size. Only three effects change their significance status due to a 4-7ms shift in effect size. We are using a mixed effects model similar to the one we used for the pilot study so we can assume that the model will help to account for the individual variances between participants. Our ability to assign slopes to the random factors in the experiment, such as participant, reduces an outlier's ability to affect the results in an extreme manner.

A QQ plot is included in Figure 4.2 as an illustration of the goodness-of-fit of the mixed effect model in relation to the dataset. The model fits the dataset well for the majority of the data points. The higher outlier RT values might be more difficult for the model to reflect if they are unrelated to the experimental conditions.

Figure 4.2: QQ plot of Mixed Effects Model Compared to a Normally Distributed Model Fit



4.2.2 Mixed Effects Factor Comparison

A summary of the mixed effects model used to represent the dataset and estimate effects can be found in Table 4.9. Right away we see that there are some estimated effects with significant p-values. There are those that are to be expected due to the identity of the intercept, object control and position one with no priming. The high significance of subject-to-subject raising and the less significant, yet still large, effect for subject-to-object raising are what we would expect to see because they are theoretically different from control structures.

I calculated the overall effects in milliseconds associated with each condition. This is done by taking the intercept and adding or subtracting the estimated effect difference associated with the appropriate factor(s). I have included the numbers I used in my calculations below in (10).

(10) Object control: 894.14
Subject control (two possible antecedents): 894.14 - 18.39 = 875.75
Subject control (one possible antecedent): 894.14 - 76.58 = 817.56
Subject-to-object(StO) raising: 894.14 - 56.86 = 837.28
Subject-to-subject (StS) raising: 894.14 - 82.08 = 812.06

The sentence structure types with lower complexity lead to lower estimated RT effects. Both subject control (one possible antecedent) and subject-to-object raising have only one

NP that has the possibility of being the referent or antecedent of the PRO or trace. Now, in (11), we will examine the overall effects when including the interaction effects of priming and position. The results show that priming type effects each sentence type in different ways. Subject control (2) is affected the most by priming type (85.5ms)

(11) Object control and syntactic priming: 894.14 - 121.36 = 772.78
Object control and non-syntactic priming: 894.14 - 59.81 = 834.33
Subject control (2), syntactic priming: 894.14 - 18.39 - 121.36 + 79.65 = 834.04
Subject control (2), non-syntactic priming: 894.14 - 18.39 - 59.81 - 67.40 = 748.54
Subject control (1), syntactic priming: 894.14 - 76.58 - 121.36 + 36.90 = 733.10
Subject control (1), non-syntactic priming: 894.14 - 76.58 - 59.81 = 757.75
StO raising, syntactic priming: 894.14 - 56.86 -121.36 + 72.54 = 788.46
StO raising, non-syntactic priming: 894.14 - 56.86 - 59.81 - 23.28 = 754.19
StS raising, syntactic priming: 894.14 - 82.08 - 121.36 + 38.04 = 728.74

Table 4.9: Linear mixed model fit by REML ['merModLmerTest']. Fixed effects estimations using the formula: RT~Condition * Position * Priming + (Condition | Participant) + (Priming | Verb) + (1 | Image).

Factor(s)	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	894.14	26.04	82.46	34.33	***0.00
Subject-to-object (StO)	-56.86	21.21	28.76	-2.68	*0.01
Subject-to-Subject (StS)	-82.08	22.24	34.48	-3.69	***0.00
Subject1 (one possible antecedent)	-76.58	22.10	33.77	-3.47	**0.00
Subject2 (two possible antecedents)	-18.39	22.14	33.85	-0.83	0.41
Positiontwo	-35.25	17.04	5442.88	-2.07	*0.04
Non-syntactic	-59.81	25.02	43.35	-2.39	*0.02
Syntactic	-121.36	24.20	40.60	-5.01	***0.00
StO:Positiontwo	41.09	20.74	5436.37	1.98	*0.05
StS:Positiontwo	30.12	23.80	5431.37	1.27	0.21
Subject1:Positiontwo	48.99	23.91	5431.10	2.05	*0.04
Subject2 :Positiontwo	28.03	24.04	5433.67	1.17	0.24
StO:Non-syntactic	-23.28	32.34	30.40	-0.72	0.48
Subject2 :Non-syntactic	-67.40	35.07	41.86	-1.92	•0.06
StO:Syntactic	72.54	31.40	28.73	2.31	*0.03
StS:Syntactic	38.04	32.06	31.26	1.19	0.24
Subject1:Syntactic	36.90	32.03	31.16	1.15	0.26
Subject2 :Syntactic	79.65	34.49	41.87	2.31	*0.03
Positiontwo:Non-syntactic	4.35	29.70	5450.30	0.15	0.88
Positiontwo:Syntactic	20.69	29.26	5436.11	0.71	0.48
StO:Positiontwo:Non-syntactic	18.55	36.09	5442.99	0.51	0.61
Subject2 :Positiontwo:Non-syntactic	23.34	41.59	5438.07	0.56	0.57
StO:Positiontwo:Syntactic	-35.09	35.85	5431.53	-0.98	0.33
StS:Positiontwo:Syntactic	-3.23	37.54	5431.19	-0.09	0.93
Subject1:Positiontwo:Syntactic	-42.22	37.60	5428.84	-1.12	0.26
Subject2 :Positiontwo:Syntactic	-46.22	41.71	5431.49	-1.11	0.27

StS raising, non-syntactic priming: 894.14 - 82.08 - 59.81 = 752.25

I completed a type III Analysis of Variance with Satterthwaite approximations to observe the significance level of the differences between the sublevels of the fixed factors. This was done using the *anova* function in RStudio. In order to use this function, I had to split the dataset into separate parts. The large differences between the conditions in the dataset would not allow for an analysis using an ANOVA. When including only raising conditions (subject-to-object and subject-to-subject raising), I found a large difference between the effects associate with the sublevels of priming (p-value = 0.00056). There was also a difference found within the sublevels of condition type (p-value = 0.077).

When only control conditions were included, the ANOVA would not compute unless the subject control (one possible controller) sentences were excluded. This is where we can really see the difference in complexity between subject control sentences with one or two possible controllers. After excluding the subject control (one possible controller) sentences, the analysis of variance showed a significant difference between the sublevels of priming type (p-value = 0.0001). This was the case for the interaction between condition and priming as well (p-value = 0.026).

As in the pilot experiment, later assessment of the testing sentences led to the realization that passive sentences could affect the results of the experiment. The main experiment contained one passive construction, a subject control (two possible antecedents) sentence using the verb phrase *blir bedt av*. When these data points were excluded from the dataset, the mixed effects model summary showed changes exclusively in cases of subject control (two possible antecedents). The changes in effect size range from 8.556ms to 12.788ms.

4.2.3 Analysis of Interaction Effects

The mixed effects model estimates significant effects for position and factor interactions as well. I will explore these further using interaction plots. I have inserted red and green arrows within the interaction plots in order to highlight the effects I will focus on. The following plots have been selected to compare between specific conditions and do not display all sentence types in one graph.

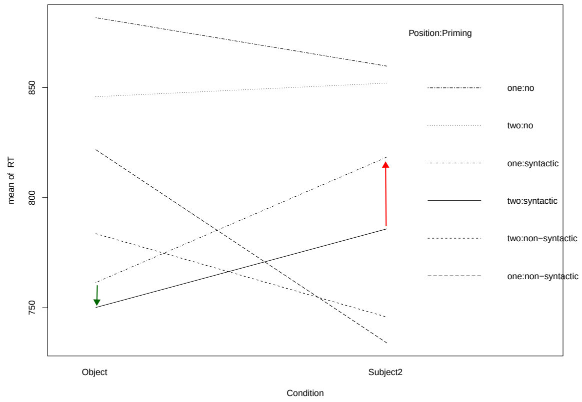
The plots in Table 4.10 illustrate the interaction effect between position and priming type in relation to object and subject control (two possible antecedents) constructions. The plot on the left side of the table includes all data and the plot on the right side excludes passive sentence constructions. Syntactic and non-syntactic priming tend to work in an opposite pattern across conditions. Syntactic priming had a small effect on object control when comparing the effects of position one and two. The same goes for non-syntactic priming and subject control. We can see that position two leads to a faster mean RT under most conditions, particularly when the image shown is the subject of the matrix clause.

The exclusion of passive test sentences almost doubles the difference in effect size for syntactically primed subject control sentences when tested at position two compared to position one. There continues to be nearly no difference in mean RT when comparing position one and two for syntactically primed object control sentences.

The next set of interaction plots in Table 4.11 compare different sentence conditions in each plot. The plot on the left contains a comparison of interaction effects between object control and subject-to-object raising constructions. There is almost no effect of position when

Table 4.10: Interaction Plots Displaying Mean RT Effects of Position and Priming Interaction on Sentence Type, Including and Excluding Passive Constructions

Including Passives	Excluding Passives



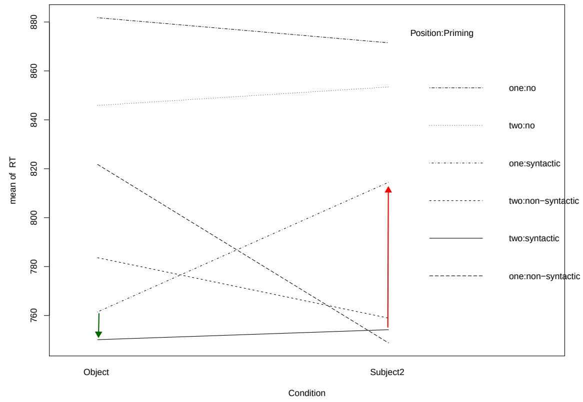
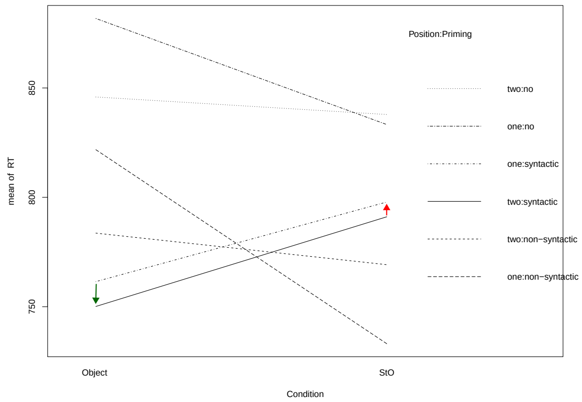
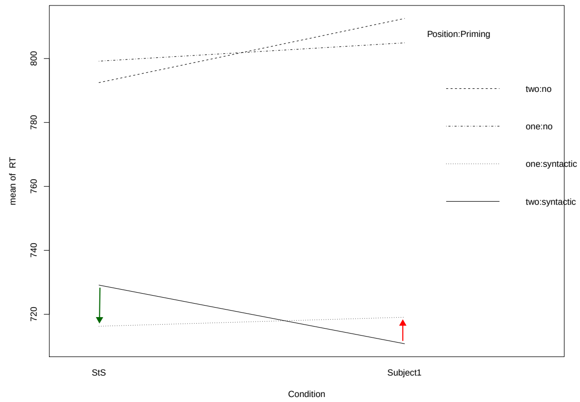


Table 4.11: Interaction Plots Displaying Mean RT Effects of Position and Priming Interaction on Sentence Types

Object control and StO Raising	StS Raising and Subject control (1)





comparing instances of syntactic priming in each condition. Though object control shows a faster mean RT when primed syntactically.

Position one, for both types of priming, works in an opposite manner for object control and subject-to-object raising. This is quite similar to the relationship between object and subject control for this testing position. It is possible that the extra syntactic and semantic constraints associated with subject-to-object raising constructions causes this similarity in possessing. When it comes to non-syntactic priming, object control and subject-to-object raising show opposite trends in mean RT in relation to position.

The final condition comparison is that between subject control (one possible antecedent) and subject-to-subject raising, shown on the right in Table 4.11. These two conditions were ideal to include in a single plot together because they match each other in complexity, with only one NP introduced in the sentence as a possible antecedent or referent. This presumably lowers the processing load of these constructions compared to the others tested in the experiment and is also why there are no instances of non-syntactic priming for these structures.

An interesting effect to notice is that of position. When syntactically primed, subject control tends to have a lower mean RT in test position two (approximately 20ms) when compared to subject-to-subject raising. The opposite effect is found across conditions when primed with an unrelated image (no priming), position two is approximately 20ms faster for StS raising than for subject control. Sentence constructions of both types show nearly identical mean RTs when syntactically primed in position one. This effect for position one holds even with no priming. Though the overall effects are small within each condition, the significant effects of position requires further consideration.

4.2.4 Pairwise Condition Analysis of Effect of Position

As position was the original point of comparison in this experiment, I created seven separate models to explore the effect of position on syntactically primed control and raising constructions. Each model contains a pairwise comparison of two sentence type conditions. The models compare levels within the raising condition to each other and to each level within the control condition. Note that the data used in this part of the analysis excludes passive constructions. Another analysis presented afterward will compare object and subject control.

Table 4.12 is a model comparing subject-to-subject raising and subject (1 possible antecedent) control. The intercept is StS raising and position one. A type III ANOVA with Satterthwaite approximations showed no significant effects.

Table 4.12: Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom ['lmerMod'], Formula: RT ~Condition * Position + (Condition | Participant) + (1 | Verb) + (1 | Image)

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	716.43	19.14	70.28	37.43	***0.00
Subject (1 Possible antecedent)	4.80	14.83	189.25	0.32	0.75
Positiontwo	12.43	14.17	838.44	0.88	0.38
Subject1:Positiontwo	-21.16	20.01	838.49	-1.06	0.29

In table 4.13, there is a model summary showing a comparison between StS raising and subject-to-object raising. The intercept is StO raising and position one. A type III ANOVA with Satterthwaite approximations showed a significant effect of condition ($F(1, 8.36) = 22.54$, $p < 0.0013$**).

Table 4.13: Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom ['lmerMod'], Formula: RT ~Condition * Position + (Condition * Position | Participant) + (1 | Verb) + (1 | Image)

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	800.71	18.73	37.10	42.74	***0.00
StS	-84.45	18.36	15.81	-4.60	***0.00
Positiontwo	-7.48	16.66	111.57	-0.45	0.65
StS:Positiontwo	19.21	22.92	197.49	0.84	0.40

Table 4.14 contains a model summary showing a comparison between StO raising and subject (1) control. The intercept is StO raising and position one. A type III ANOVA with Satterthwaite approximations showed a significant effect of condition ($F(1, 6.48) = 36.50$, $p < 0.0007$***).

Table 4.14: Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom ['lmerMod'], Formula: RT ~Condition * Position + (Condition * Position | Participant) + (1 | Verb) + (1 | Image)

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	801.82	20.39	55.79	39.33	***0.00
Subject1	-80.58	17.12	17.80	-4.71	***0.00
Positiontwo	-8.26	15.57	812.45	-0.53	0.60
Subject1:Positiontwo	0.31	21.76	812.57	0.01	0.99

Table 4.15 shows a model summary comparing StS raising and subject (2 possible antecedents) control. The intercept is StS raising and position one. A type III ANOVA with Satterthwaite approximations showed a significant effect of condition ($F(1, 21.81) = 10.58$, $p < 0.0037$**) and a significant interaction effect between condition and position ($F(1, 96.81) = 4.97$, $p < 0.028$*).

Table 4.15: Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom ['lmerMod'], Formula: RT ~Condition * Position + (Condition * Position | Participant) + (1 | Verb) + (1 | Image)

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	716.48	18.14	42.23	39.50	***0.00
Subject2	99.97	25.08	38.80	3.99	***0.00
Positiontwo	11.44	16.40	89.76	0.70	0.49
Subject2 :Positiontwo	-69.74	31.27	96.78	-2.23	*0.03

In table 4.16, the model shows a comparison between StS raising and object control. The intercept is object control and position one. A type III ANOVA with Satterthwaite approximations showed a significant effect of condition ($F(1, 69.72) = 4.84$, $p < 0.031$*).

Table 4.16: Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom ['lmerMod'], Formula: RT ~Condition * Position + (Condition * Position | Participant) + (1 | Verb) + (1 | Image)

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	760.92	26.17	50.67	29.08	***0.00
StS	-45.01	19.65	99.74	-2.29	*0.02
Positiontwo	-11.85	22.86	62.36	-0.52	0.61
StS:Positiontwo	24.30	27.68	82.03	0.88	0.38

The model summary in Table 4.17 compares StO raising and subject (2) control. The intercept is StO raising and position one. A type III ANOVA with Satterthwaite approximations showed a small effect of position ($F(1, 56.65) = 3.27$, $p < 0.076$•).

Table 4.17: Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom ['lmerMod'], Formula: RT ~Condition * Position + (Condition * Position | Participant) + (1 | Verb) + (1 | Image)

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	800.65	18.90	27.02	42.37	***0.00
Subject2	10.42	29.71	28.96	0.35	0.73
Positiontwo	-7.17	17.64	157.90	-0.41	0.69
Subject2 :Positiontwo	-44.11	34.09	139.40	-1.29	0.20

Finally, in Table 4.18, there is a model summary showing a comparison between StO raising and object control. The intercept is object control and position one. A type III ANOVA with Satterthwaite approximations did not show any significant effects.

Table 4.18: Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom ['lmerMod'], Formula: RT ~Condition * Position + ((Condition * Position) | Participant) + (1 | Verb) + (1 | Image)

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	760.85	25.86	34.26	29.42	***0.00
StO	39.87	26.41	11.28	1.51	0.16
Positiontwo	-11.77	23.40	577.25	-0.50	0.62
StO:Positiontwo	3.26	28.76	574.62	0.11	0.91

4.2.5 Control and Position: Non-syntactic Priming as the Baseline

To further consider the effect of position in control structures, I compared the effects of position in object and subject control using a non-syntactic priming baseline. The dataset included only the object and subject (2 possible antecedents) control conditions and only instances in which they were syntactically primed by the correct image of the PRO antecedent. Using the data from object and subject control sentence presentations that were primed non-syntactically, I created a baseline using minimal contrasts. Since non-syntactically primed presentations of each sentence differ from syntactically primed presentations only by one item (whether or not the image is the correct PRO referent) these were the best to contrast. This also allows us to account for the fact that the images were seen in word form previously in the sentence and could be affected by semantic priming or association.

I created a mixed effects model that contained exclusively data on object and subject (2 possible antecedents) conditions, shown in Table 4.19. Then I estimated the effects for each condition in each position with each type of priming. I subtracted the non-syntactic priming condition in the same position with the opposite control type from the syntactic priming condition. See (12) for an example. In this example, 737.62 would be subtracted from 760.17.

(12) Object control, syntactic priming, position one: 819.35 - 59.18 = 760.17
Subject control, non-syntactic priming, position one: 819.35 - 81.73 - 59.18 + 141.84 = 737.62

Table 4.19: Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom ['lmerMod'], Formula: RT ~Condition * Position * Priming + ((Condition + Position + Priming) | Participant) + (1 | Verb) + (1 | Image)

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	819.35	28.65	65.52	28.60	***0.00
Subject2	-81.73	25.26	609.35	-3.24	**0.00
Positiontwo	-27.56	25.74	654.83	-1.07	0.28
Syntactic	-59.18	25.31	616.47	-2.34	*0.02
Subject2 :Positiontwo	45.45	35.19	795.90	1.29	0.20
Subject2 :Syntactic	141.84	35.11	795.36	4.04	***0.00
Positiontwo:Syntactic	15.42	35.27	795.99	0.44	0.66
Subject2 :Positiontwo:Syntactic	-62.27	49.86	794.65	-1.25	0.21

In the baseline condition and the data condition that the baseline is assigned to, an image is shown in the same position and is previously mentioned within the sentence. The difference is that the image shown is either the correct PRO antecedent or, in the baseline, the incorrect PRO antecedent. After all syntactic priming data was given a baseline comparison the effect of that baseline was subtracted from each data point contained within the syntactic priming dataset. The final dataset contained object and subject (2) constructions and syntactic priming. The new RT measurements of each presentation was called RT3 and used to create another mixed effects model. The summary is shown in Table 4.20. This dataset includes passive constructions. A type III ANOVA with Satterthwaite approximations was completed for the model below. No significant effects were found across levels.

Table 4.20: Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom ['lmerMod'], Formula: RT3 ~Condition * Position + ((Condition * Position) | Participant) + (1 | Verb) + (1 | Image)

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	22.09	29.55	15.74	0.75	0.47
Subject2	-18.93	25.24	61.28	-0.75	0.46
Positiontwo	-27.46	23.78	143.78	-1.15	0.25
Subject2 :Positiontwo	23.02	35.16	78.39	0.65	0.51

An interaction plot is included in Figure 4.3 that illustrates the effect of position on condition after applying the non-syntactic baseline to the dataset. We can see that the mean RT for position one decreases for object control in comparison to the previous plots presented for the main dataset. Position one and two do not show a large difference for subject control.

Since passive constructions have been shown to affect the mean RT of subject (2) control sentences, I have used the same technique to create a baseline for the dataset that excludes passive sentences. In Table 4.21, a summary of the original dataset containing only object and subject (2) control constructions and excluding passives is shown.

Once the appropriate baseline was assigned to all syntactic priming data points, I created another mixed effects model with the altered RT values. The estimated effects are displayed in Table 4.22. The type III ANOVA with Satterthwaite approximations showed no significant effects.

Figure 4.3: Interaction Plot Displaying the Effect of Position on Condition, Non-syntactic Baseline

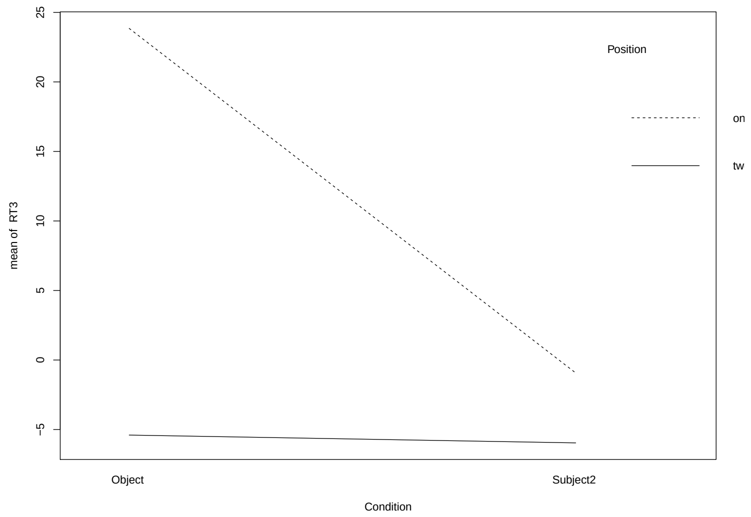


Table 4.21: Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom ['lmerMod'], Formula: RT ~Condition * Position * Priming + ((Condition + Position + Priming) | Participant) + (1 | Verb) + (1 | Image)

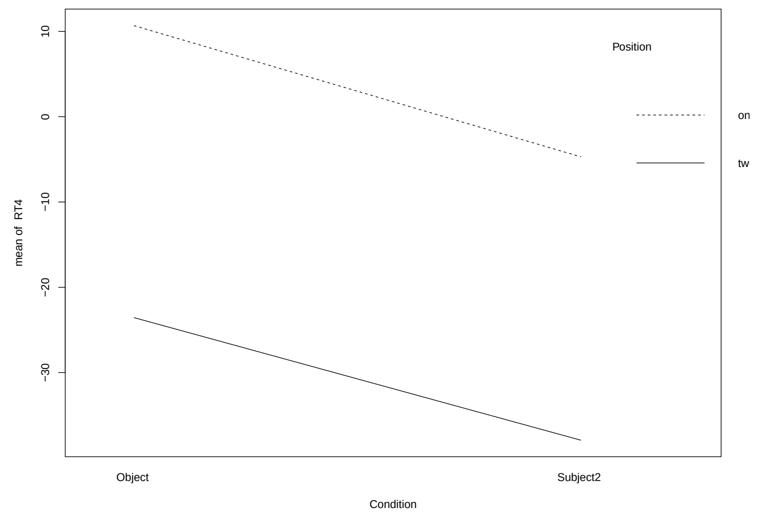
	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	819.16	27.27	92.60	30.03	***0.00
Subject2	-68.36	27.20	483.08	-2.51	*0.01
Positiontwo	-27.06	25.33	519.95	-1.07	0.29
Syntactic	-58.35	24.44	617.76	-2.39	*0.02
Subject2 :Positiontwo	49.93	37.17	686.68	1.34	0.18
Subject2 :Syntactic	121.54	37.43	683.11	3.25	**0.00
Positiontwo:Syntactic	13.29	34.45	682.33	0.39	0.70
Subject2 :Positiontwo:Syntactic	-86.18	52.70	690.17	-1.64	0.10

Table 4.22: Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom ['lmerMod'], Formula: RT4 ~Condition * Position + ((Condition * Position) | Participant) + (1 | Verb) + (1 | Image)

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	9.16	27.48	24.98	0.33	0.74
Subject2	-13.78	34.06	11.76	-0.40	0.69
Positiontwo	-33.14	23.38	100.61	-1.42	0.16
Subject2 :Positiontwo	7.29	35.36	121.85	0.21	0.84

The interaction plot in Figure 4.4 on the following page shows the effect of position on control type. Notice the difference in scaling on the y-axis when comparing to the plot in Figure 4.3. The exclusion of passive constructions leads to a decrease in mean RT for all points. Both positions show a trend of decreased RT in the subject control condition. Position two displays a lower mean RT in both subject and object control, with an approximate 35ms speed up compared to position one.

Figure 4.4: Interaction Plot Displaying the Effect of Position on Condition, Excluding Passives, Non-syntactic Baseline



4.3 Summary of Results

In the pilot study, we observed significant differences for test position one in comparison to position two and three. For subject control sentences, position two and three displayed significantly faster decision times when compared to position one. Object control sentences showed slower decision times in position two and three, with the fastest mean RT in position one.

After limiting the analysis to only syntactically primed presentations and excluding the interaction effect between priming and position, the effects for position one and two in both types of control remained. The effects of position three for the subject control condition did not. The mean RT in this condition significantly decreased, leaving position two with the fastest decision time for subject control.

In the main experiment, the results confirmed the difference in effect of position when comparing position one and two. Object control sentences showed a faster decision time in position one while subject control sentences showed a faster decision time in position two. These effects were similar to those reported in the pilot study. The removal of passive constructions strengthened the effects of reactivation found in position two for subject control.

Non-syntactic and syntactic priming were also compared in the statistical analysis of control constructions. After assigning a non-syntactic baseline to the syntactically primed data points, greater effects were found for position two. Faster mean RTs were noted for both object and subject control conditions in position two.

The effects for position in the raising conditions were not as strong. I recorded faster decision times in position one for subject-to-subject raising. There was almost no effect of position in subject-to-object raising sentences, but there was a less than 10ms speedup in position two.

Some of the hypotheses that I introduced in Chapter 1 can be rejected based on the findings presented in this chapter. The one that can be rejected with the most certainty is that control and raising are processed in the same way and, therefore, both involve NP-traces.

Control conditions differ significantly from raising conditions in the main experiment.

The results also show that the position in which the referent of a PRO or a trace reactivates and shows priming facilitation effects differs between control and raising sentences. We can reject the null hypotheses relating to referent reactivation for control and raising shown below in (15) and (16).

(13) No reactivation of PRO antecedents occurs during the processing of control sentences.

(14) No reactivation of raising trace referents occurs during the processing of raising sentences.

We can tentatively reject the hypotheses in (17) and (18) as well. This is because the results of these experiments need to be replicated and considered in various other languages before fully rejecting these hypotheses. Future research on control must again consider the working hypotheses discussed in this thesis.

(15) Reactivation of PRO antecedents occurs before the infinitive marker in a control sentence.

(16) Reactivation of raising trace referents occurs after the infinitive marker in a raising sentence.

Chapter 5

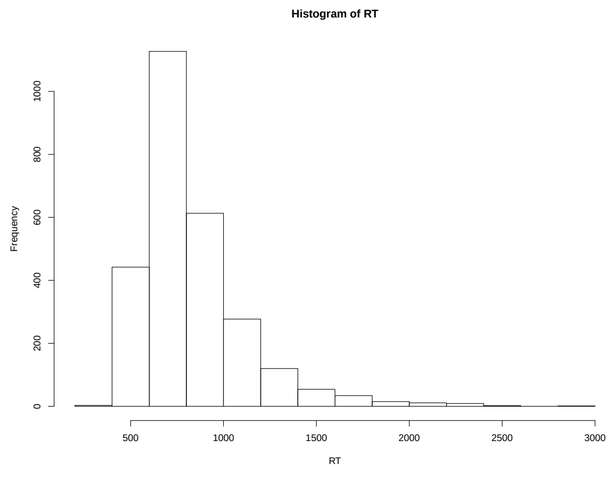
Data Exploration and Quality Checking

This section will include the process of quality checking the data, an outlier analysis, and general data exploration. I will include all data preparation that took place after the original cleaning of the data, along with visual aids and explanations of my decisions.

5.1 Pilot Study Exploration

To generate a visual representation of the dataset, a histogram was created using the *hist* function in RStudio. The distribution of reaction times (RTs) in ms can be seen in Figure 5.1. There is a long tail on the high end of RTs and small number of RTs under 400ms.

Figure 5.1: Histogram of Original Pilot Study Data



I chose to restrict the dataset to a minimum RT of 400ms and a maximum RT value of 1800ms. The minimum RT value was selected because I estimated this to be the fastest possible time in ms that a participant could take to process the image shown, make a decision, and then act on their decision by pressing the button. The maximum RT value was selected to cut off any high RTs that could affect the statistical analysis and were likely unrelated to the experiment. I made this decision by calculating individual bin values for each bar of the histogram, as shown in Table 5.1. Then I selected a cutoff point at which bin values showed a large decrease in RT quantity. The goal was to retain over 95% of the data. Limiting data points to those with RT values between 400 and 1800ms allowed 98.5% to be included in the analysis.

Table 5.1: Pilot Study RT Histogram Bin Values

Bins in ms	200-400	400-600	600-800	800-1000	1000-1200	1200-1400
Number of RTs	3	442	1127	613	277	120
	1400-1600	1600-1800	1800-2000	2000-2200	2200-2400	2400-2600
	54	34	15	11	9	2
	2600-2800	2800-3000				
	0	1				

The final data distribution is shown in the histogram in Figure 5.2. We can see that the outlier RT values have been mostly eliminated and the bulk of the data remains. The overall distribution is closer to being normalized. Even so, there is still a tail on the higher end of the histogram. It is important to consider that there are a variety of reasons that these higher values are present in the data. These can include factors unrelated to the experiment.

Figure 5.2: Histogram of Pilot Study Data with RT Values from 400 to 1800ms

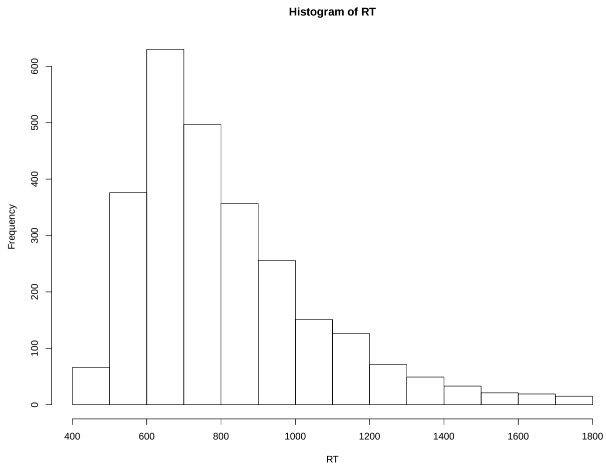
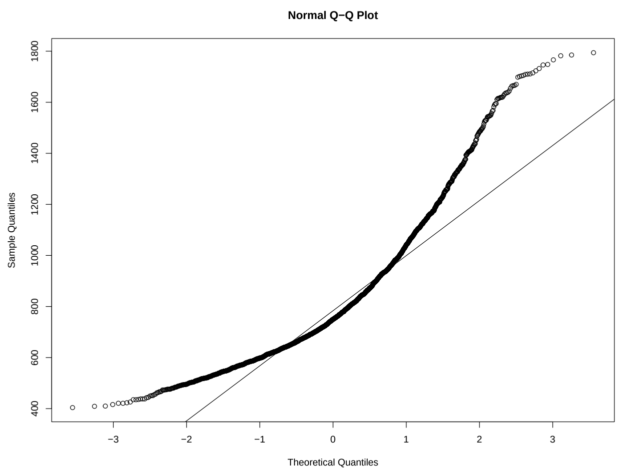


Figure 5.3: QQ plot of Pilot Study Data Compared to a Normally Distributed Dataset

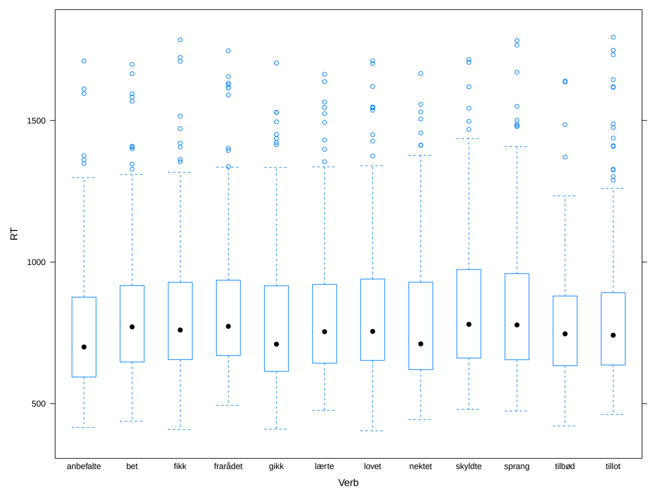


A quantile-quantile plot (QQ plot) was created to compare the distribution of the experimental data points to that of a normally distributed dataset. This QQ plot is shown in Figure 5.3. The plot shows that there are higher data points that diverge from normality, along with some on the lower end. A slight divergence from normality is expected when doing experimental work, as we do not expect a participant to respond randomly. Especially high RTs were likely due to random events or distractions that took place during the experiment, but we cannot exclude the possibility that at least some were due to an increase in sentence processing difficulty.

To conduct an outlier analysis of the random experimental factors, I created box and whisker plots in RStudio using the *bwplot* function. This was done to look for possible outliers within the sublevels of each factor. I used the *lattice* package to create these plots. Outlier analyses are helpful in determining whether or not an effect in the data is driven by a specific item within a set.

First, the RTs recorded for each verb were plotted, as shown in Figure 5.4. I found there to be no major outliers when it came to individual verbs. There are a few verbs which display a slightly faster RT median value, but this is to be expected. The boxes for each verb are nearly aligned with each other. The upper limit of the box is the 75th percentile and the lower limit of the box is the 25th percentile (Dong, 2012). This means that the majority of the data is within the range of the RT values represented by the box. There is no sign that a particular verb is driving effects in the experiment.

Figure 5.4: Boxplot of RTs per Verb



In Table 5.2, each verb is listed along with the number of times it is recorded in the dataset. Due to incorrect answers and the deletion of outlier RTs, the number differs between verbs. The quantity of each individual verb in the dataset ranges from 218 to 232, with typical values around 220.

A similar result is found in Figure 5.5, displaying the RTs per image stimuli. No image is shown to individually effect experimental results. The elephant and hippopotamus have longer ranges of average RTs. Participants reported some difficulty distinguishing between the two animals, but they do not display outlier tendencies. Table 5.3 displays the image type and the number of each represented in the dataset. We can see that the elephant and hippopotamus images occur less often. This is because these images led to more incorrect answers, RTs below 400ms, or RTs above 1800ms during the experiment.

Table 5.2: Number of Verbs Represented in Dataset

Verb	Quantity
anbefalte	218
bet	219
fikk	219
frarådet	221
gikk	232
lærte	219
lovet	223
nektet	229
skyldte	219
sprang	218
tilbød	222
tillot	228

Figure 5.5: Boxplot of RTs per Image Stimuli

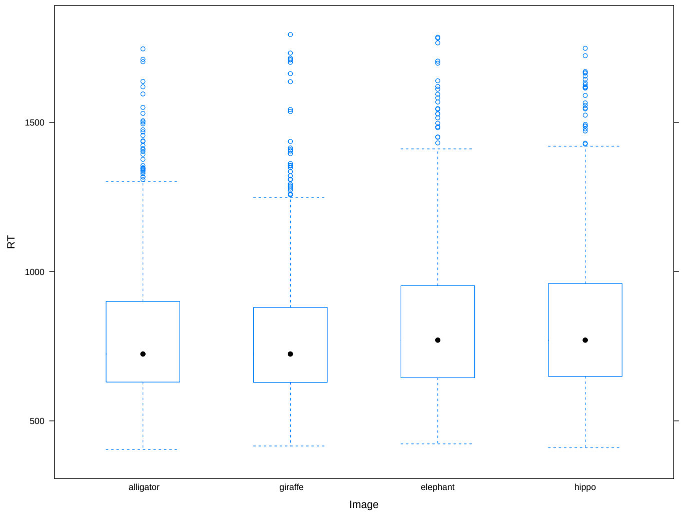


Table 5.3: Number of Image Stimuli Represented in Dataset

Image	Quantity
alligator	673
giraffe	678
elephant	656
hippo	660

The final factor to undergo an outlier analysis was the participant. This boxplot is included in Figure 5.6. The majority of participants display similar RT medians. There are a couple with overall faster RTs, such as P12 and P21. P18 and P6 show generally slower RTs. It is possible that these participants used different techniques to complete the task presented in the experiment or simply that they were more cautious when making their decisions.

Figure 5.6: Boxplot of RTs per Participant

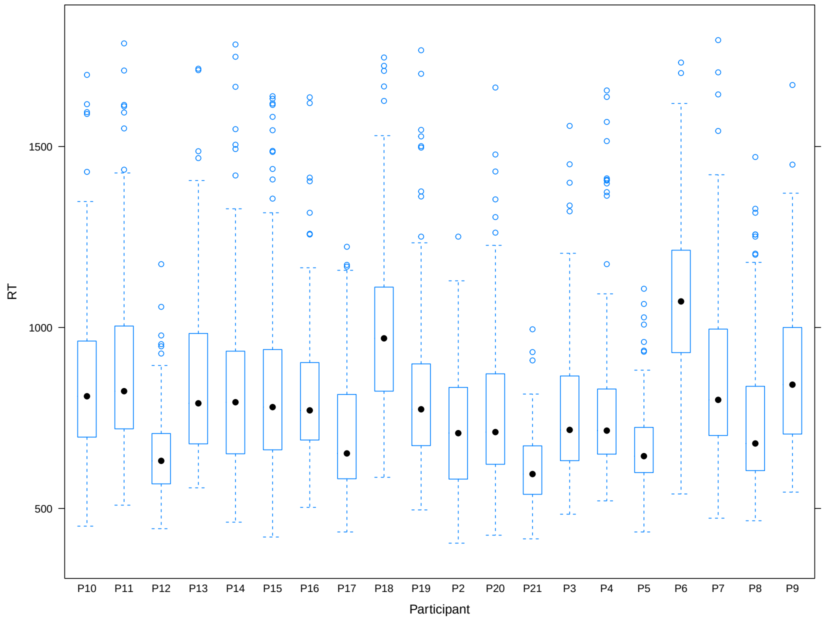


Table 5.4: Median RT Values Per Participant

Participant	Median RT (ms)
P10	810
P11	824
P12	631.5
P13	790.5
P14	793.5
P15	780
P16	771
P17	652
P18	970
P19	774
P2	708
P20	711
P21	595
P3	717
P4	715
P5	644.5
P6	1072
P7	800
P8	679.5
P9	842
All Participants	750

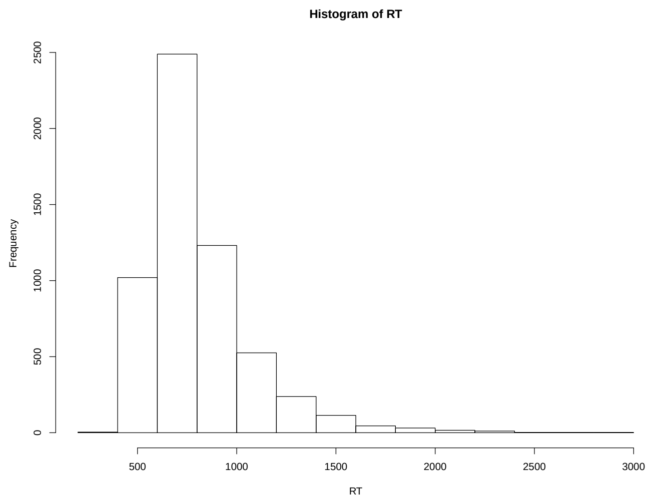
Using the *aggregate* function in RStudio, I calculated the median RT values per participant in Table 5.4. I considered P6 to be a possible effect driver and outlier in the dataset because the difference between its median RT (1072ms) and the overall RT of the dataset

(750ms) was the most extreme (322ms).

5.2 Main Experiment Exploration

I began my analysis of the dataset by creating a histogram, enabling me to visualize the distribution of data. This graph is shown in Figure 5.7. It looks similar to the histogram that was created in the previous section using the pilot study data. There is a long tail on the high end of RTs.

Figure 5.7: Histogram of Main Study Data



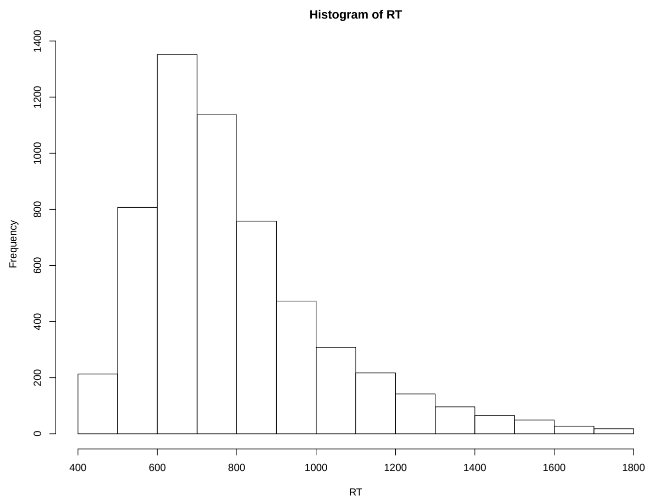
The extreme high RT responses and the extreme low responses were shaved off of the dataset. This was done using the same high and low limits as in the pilot analysis, 400ms to 1800ms. I made this decision using the same techniques previously utilized while subsetting the pilot study dataset. The lower limit was selected to ensure that the participant physically had time to process the information and make a decision. I then calculated the number of RT measurements in each histogram bin and selected the higher limit based on RT distribution across bins. The values of these bins are shown in Table 5.5. Limiting the dataset to RT values between 400 and 1800ms allowed for 98.85% of the data points to be included in the analysis.

Table 5.5: Pilot Study RT Histogram Bin Values

Bins in ms	200-400	400-600	600-800	800-1000	1000-1200	1200-1400
Number of RTs	4	1020	2489	1231	525	238
	1400-1600	1600-1800	1800-2000	2000-2200	2200-2400	2400-2600
	114	45	31	16	11	2
	2600-2800	2800-3000				
	1	1				

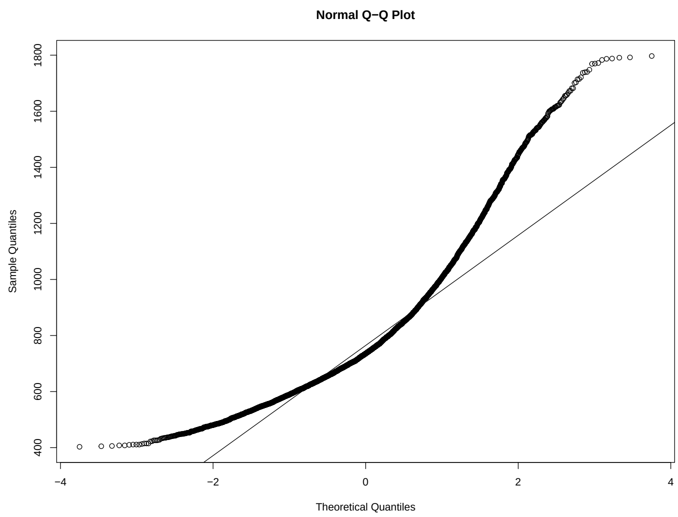
The resulting histogram is displayed in Figure 5.8. A tail remains on the higher end of RTs, but we cannot expect a perfect normal distribution of data points. The fact that the distribution of this dataset is strikingly similar to that of the pilot experiment is significant when considering the quality of the experimental design because it reflects the repeatability of the experiment.

Figure 5.8: Histogram of Main Study Data with RT Values from 400 to 1800ms



I used a QQ plot, Figure 5.9, to assess the distribution of data points in the dataset. The line on the graph is one showing the expected normal distribution of the sample as a line. We can see that the distribution of the data from the main experiment is skewed, but that the bulk of the data is close to following the linear trend of the normally distributed data sample. The outliers on either end of the dataset can be related or unrelated to the experiment and testing conditions.

Figure 5.9: QQ plot of Main Study data Compared to a Normally Distributed Dataset



In consideration of the outlier RTs in the dataset, I conducted an outlier analysis for each random factor included in the experiment: verb, image, and participant. The *lattice* package was employed to create box and whisker plots in RStudio with the *bwplot* function.

We will begin by plotting the RTs recorded for each verb. The resulting boxplot is show in Figure 5.10. Though some verbs have larger RT ranges than others, the plot does not show any to be particular outliers.

Figure 5.10: Boxplot of RTs per Verb

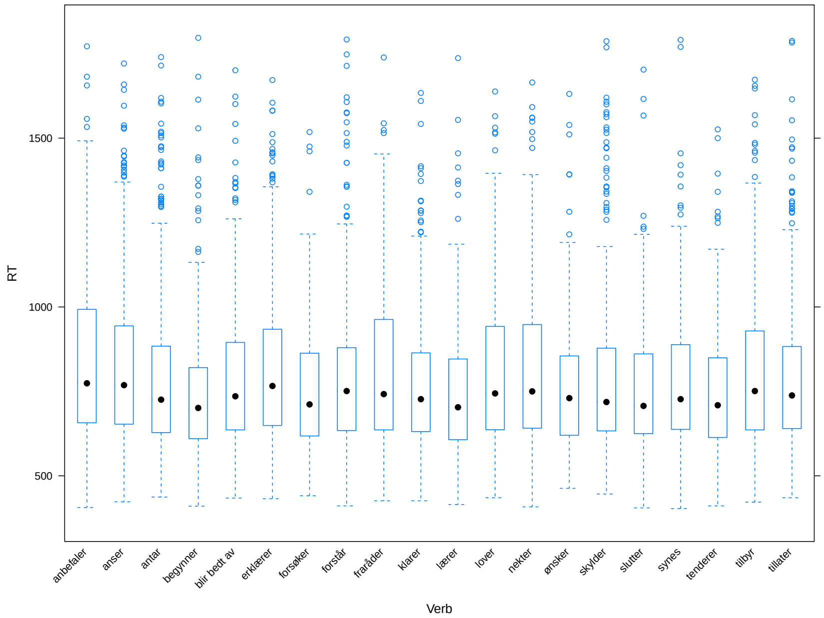
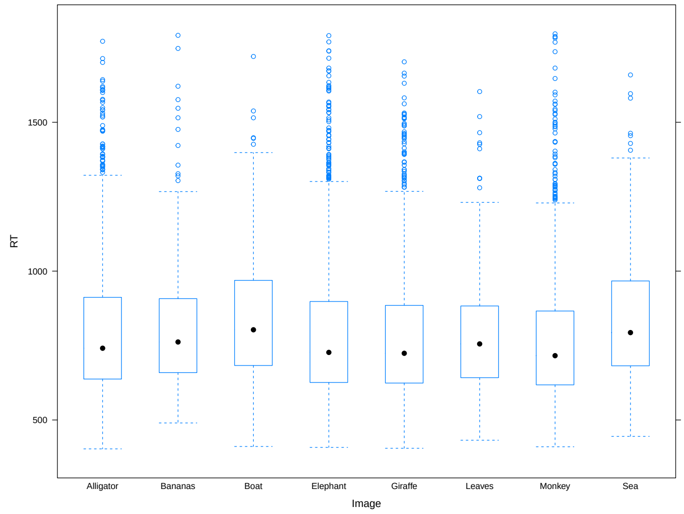


Table 5.6: Number of Verbs Represented in Dataset

Verb	Quantity
anbefaler	229
anser	466
antar	482
begynner	240
blir bedt av	226
erklærer	473
forsøker	240
forstår	471
fraråder	226
klarer	237
lærer	238
lover	235
nekter	237
ønsker	242
skylder	236
slutter	245
synes	236
tenderer	243
tilbyr	230
tillater	230

Each verb is listed in Table 5.6 along with the number of times it is recorded in the dataset. Originally, the number of verb presentations were equal, except for those used for subject-to-object raising. This is no longer the case due to response errors and outliers, which have been deleted. The large differences associated with the verbs used for subject-to-object raising were part of the design of the experiment. This was done because inanimate NPs and images were needed in these test sentences. See the methods chapter for further discussion.

Figure 5.11: Boxplot of RTs per Image Stimuli



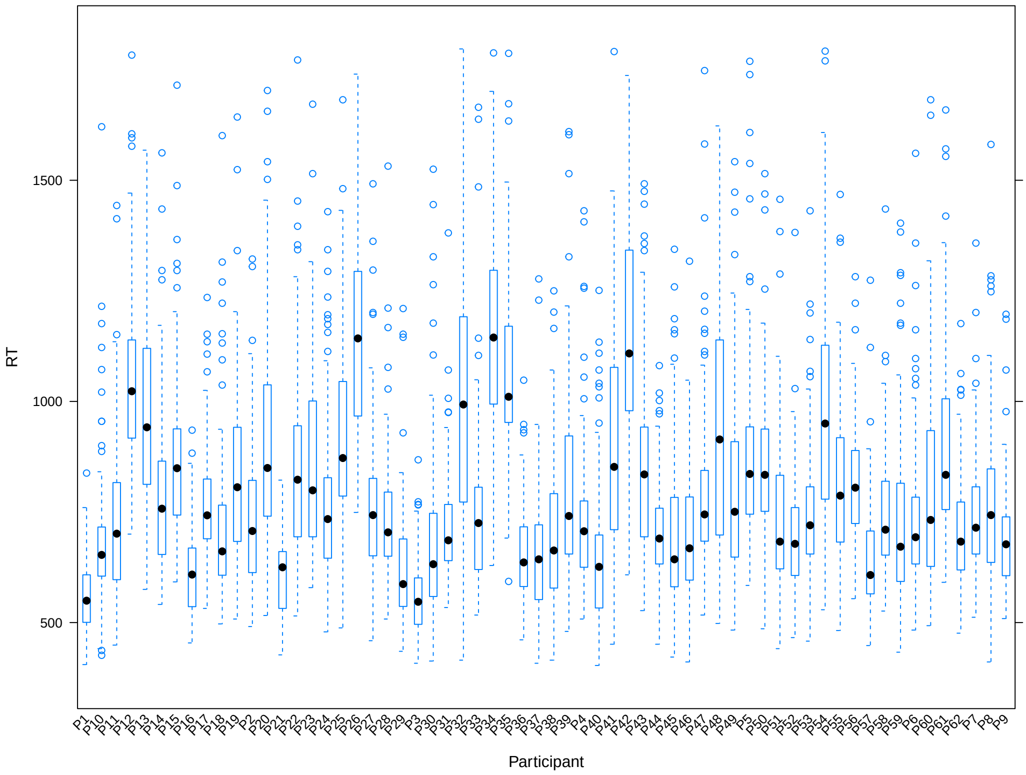
A boxplot for image stimuli is show in Figure 5.11. The images of inanimate objects used throughout the experiment tend to have a slight delay in RTs, with *boat* and *sea* showing the largest effects. This is reasonable when we consider that these images were showed less frequently in comparison to the images of animate (live) objects. The differences are not large enough to cause concern but should be kept in mind.

As previously mentioned, the images of inanimate objects were presented less frequently and this is most apparent in Table 5.7. The differences between animal images are due to the editing and cleaning of the data. The largest difference is 3% and is found between the *elephant* and *monkey* images (36 presentations). Even so, the number is small in relation to the overall number of presentations per animal image.

Table 5.7: Number of Image Stimuli Represented in Dataset

Image	Quantity
Alligator	1167
Bananas	243
Boat	225
Elephant	1166
Giraffe	1193
Leaves	234
Monkey	1202
Sea	232

Figure 5.12: Boxplot of RTs per Participant



The next outlier analysis I completed was the assessment of the individual participants who took part in the experiment. The boxplot in Figure 5.12 contains the majority of participants within a specific range of RTs, yet there are a handful of outliers, particularly on the higher range of RTs. It is a possibility that the participants used various strategies when completing the task, but equally possible is that some were more careful than others in selecting an answer.

To pinpoint possible outliers, I used the *aggregate* function to calculate the median RT values per participant. The median RT value of all participants in the dataset is 793.64ms. I considered P26 (1142.5ms), P34 (1144.5ms), and P42 (1108.5ms) to be possible outliers due to the difference between their median RT values and that of the overall dataset (348.86, 350.86, 314.86ms).

Chapter 6

Discussion

6.1 Overview of the Results and Implications

Results from the pilot study were calculated using data from a sample of twenty participants. The statistical analysis was discussed in Chapter 5. The significant effects were estimated by conducting multiple ANOVAs using mixed effects models created in RStudio. These significant effects were found for priming, the interaction between priming and control type, and the interaction effect between the three fixed factors of priming, position, and control type. Further investigation of the interaction effects of position and priming on the type of control sentence presented provided evidence of large contrasts in effect sizes, particularly when contrasting differences in position.

The main experiment included data from 62 participants and the summary and statistical analysis of the results was presented following the pilot study in Chapter 5. I used mixed effects models to calculate estimated effects for the sublevels of each factor and ANOVAs to estimate significant effects and variance. Significant effects were found for pairwise comparisons of condition. The interaction between condition and position was significant when comparing StS raising to subject (2) control. Position two was faster in the subject control condition. Position showed an effect when comparing StO raising to subject (2) control. These effects show a difference in the processing of control and raising antecedent/referent reactivation and assignment.

Recalling that a presented image was previously mentioned in word form when it was not coreferent with PRO was found to show effects. This was possibly characterized by a non-linguistic search in memory. The data from these non-syntactic priming instances were used as a baseline, which was deducted from the syntactic condition when PRO was coreferent with the picture shown. I did this in order to calculate the syntactic priming effect of coreference with PRO after accounting for the possibility of participants using a simple memory search to match the image and word from the sentence. Using this non-syntactic priming baseline, I showed that semantic recency and linear distance can affect possible referent activation.

After excluding passive constructions, there was a strong effect of position. These sentences were excluded because passive constructions switch the linear distance attributed to the subject and object of the matrix clause and might add an extra effect of linear distance. The interaction plot between position and condition showed a faster mean RT for both object and subject (2) control in position two (approximately 35ms).

Data from both experiments provides empirical evidence that supports the theory that passive constructions affect the processing of control. This brings into question the importance of the role of syntax in the processing of control and assignment of PRO antecedents. In this chapter, I will discuss how the main findings from the two experiments relate to the original hypotheses and what this means in relation to theoretical perceptions of control and how it is processed.

6.2 Control Versus Raising

Previously, in the background chapter, we explored the roots of control and raising along with their similarities and differences. The first impression that these two phenomena give is that they are the same type of sentence construction. After all, they are both structured in the same way syntactically. It is once we look into the semantics behind these constructions that we begin to understand the complexities behind their differences.

There are some theories on control and raising that limit the dissimilarities between the two sentence constructions. I discussed Hornstein (1999)'s theory of control and movement in Chapter 2. Under this theoretical view of control, PRO does not exist and instead there is a regular NP-trace. Though the semantic differences remain, the existence of a trace leads to the idea that control would be processed in a similar way as raising. As raising constructions contain an NP-trace, immediate reactivation of trace referents is expected to take place. This expectation stems from prior research on NP-traces within various sentence construction types (Nicol, 1988; Osterhout and Nicol, 1988; Nicol and Swinney, 1989; Hestvik et al., 2005, 2010).

To aid in the discussion, I will include the examples of control (a) and raising (b) that were used in the background chapter in (1).

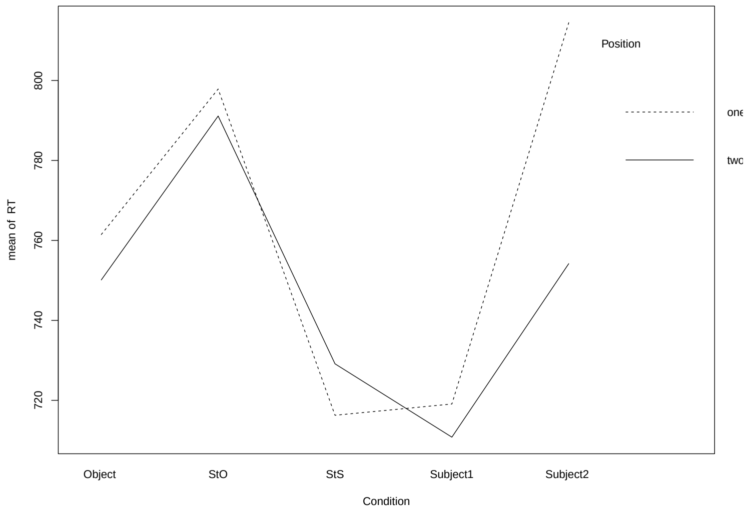
(1) a. Jean persuaded Robert_j PRO_j to leave.
b. Jean wants Brian_m t_m to leave.

In these examples, the PRO and raising trace are located in the subject position in the subordinate clause. This was the test position one in the pilot and main experiment. If we considered there to be a trace (t) in this position for both control and raising then we would expect to see similar trace reactivation patterns in the experimental results. Below in Figure 6.1 is an interaction plot comparing the mean RT for each condition in position one and position two when primed syntactically.

The results chapter introduced these effects already; however, this plot is a good illustration of the results of position reactivation. For each of the three control condition types, there is a faster mean RT in position two. A significant effect is shown for subject (2) control. When looking at the raising conditions, the subject-to-subject raising condition shows a faster mean RT for position one. This immediate reactivation was expected. The subject-to-object condition does not follow this pattern, but the difference in position is less than 10ms. It is possible that this condition was complicated by the extra constraints it has in Norwegian syntax. These were discussed in Chapter 2.

The differences found between control and raising sentence constructions in relation to position of antecedent/referent reactivation provides support to theoretical claims that these are two separate syntactic phenomena. Since PRO does not act the same as a typical NP-

Figure 6.1: Interaction Plot Displaying the Effect of Position on Condition, Excluding Passives, Syntactic Priming Only



trace, it is likely not a trace as claimed by the movement theory of PRO. It is important to keep in mind that control sentences contain an extra theta role that requires distribution and could cause a delay in reactivation position because of the size of the processing load.

The purpose of this section is to point out the support for the purposed dissimilarities between control and raising and to provide empirical evidence of their processing differences. Though I cannot pinpoint the syntactic, semantic, or pragmatic aspects of control that cause these differences, I can argue that control structures do not contain a regular NP-trace. Using PRO as a null subject seems to be necessary when considering the syntax of control. The reactivation results also do not simply reflect some general process of movement, considering the results vary between condition and sublevels of each condition.

6.3 Position and Processing

The experimental work presented in this thesis was conducted to investigate the process of co-reference assignment within control structures and trace activation within raising structures. My goal was to compare the antecedent/referent reactivation that occurs during the possessing of these two syntactic phenomena by testing the position in which it takes place. The results of the statistical analysis show that reactivation effects occur in different sentential positions when comparing control and raising reaction time data.

Raising sentences show effects in test position one, before the infinitive marker, while control sentences show effects in test position two, after the infinitive marker. In the last section, I explained how this supports the difference between control and raising constructions. Now I will focus on what this difference in reactivation position could mean for the processing and sentence structure of control.

The most common position for PRO to be placed within a control sentence is in the specifier position of the tense phrase (TP). In relation to the examples in this thesis, this would be position one, before the infinitive marker. This has been argued to be the correct position of

PRO because of syntactic binding principles and characteristics of infinitive markers (Radford, 2004). Another account of the positioning of PRO is one where it remains internalized within the verb phrase (VP) (Baltin, 1995). This would be position two, after the infinitive marker.

The data presented thus far supports Baltin's account of control and PRO positioning. Reactivation effects of PRO antecedents were found in position two so it is possible that PRO does not leave the VP to occupy the subject position of the control clause. If this is the case, co-reference assignment in control structures would not be a delayed process. This hypothesis can be tested using a greater variety of control sentence constructions. Does reactivation also take place when PRO appears at the beginning of a sentence?

Another possibility to consider because of this effect of position is that the infinitive marker is an integral part of PRO reactivation. Since the antecedent of PRO shows reactivation effects after the infinitive marker, it is possible that the infinitive maker is necessary in order to trigger this reactivation. This could boil down to a person's expectations during sentence processing. Consider the examples given in (2).

(2) a. Sally promised.
b. Sally promised to go home.
c. Sally seemed. *
d. Sally seemed to be happy.

The sentence in (a) is an acceptable sentence. Though the reader/listener expects to be told what Sally promised, the sentence itself is grammatically correct. It can easily be expanded upon and turned into a control sentence as seen in (b). Even so, this expansion is not automatically assumed by the reader/listener. The sentence in (c), however, is ungrammatical so the reader/listener predicts that it will continue into a raising sentence such as (d). Is this expectation driving some of the results? In particular, it could be driving the difference in effect of position for control versus raising.

If we acknowledge that people incorporate the principle of economy and least effort into their language, it is reasonable to assume that someone might utter (a) and expect the listener to fill in the gaps using context or their previous knowledge of the situation. At what point during sentence processing does this expectation of a sentence ending shift to that of it continuing? The findings in this thesis support the hypothesis that the presentation of an infinitive marker initiates the antecedent reactivation/assignment process. This can be tested using languages that have control constructions excluding infinitive markers.

Using position data, we can also consider the cognitive faculties employed during co-reference processing in control sentences. The overall analysis of the data showed object control having faster reaction times than that of subject control, but, after introducing a non-syntactic priming baseline, this was no longer the case. Minimizing the effects of recency and semantic familiarity, I found that subject control showed a faster RT in both position one and position two in comparison to object control (see Figure 4.4 in the results chapter).

If we simply relied on memory and search functions to assign co-reference, we would expect to see a faster mean RT for object control, at least in position one. Position one directly precedes the object NP that is being reactivated during assignment. As this does not occur once semantic familiarity is controlled for, the reactivation effects are not the result of a search for the closest possible antecedent. Similar to the conclusions of Osterhout and Nicol

(1988), the results do not support the use of the Most Recent Filler strategy during antecedent assignment. If only the Most Recent Filler strategy was used during this process then there would not be a difference depending on PRO coreference, as was observed. This means that there are more complex processes at work than just those of associated with our general cognitive faculties.

6.4 A Unified Theory of Control

Many of the theoretical issues surrounding the phenomenon of control have arisen because a universal theory of control has yet to be developed that is applicable across all languages. The characteristics of PRO vary greatly across languages and the current PRO Theorem is unable to account for this. For example, PRO can obtain case in languages such as Icelandic (Sigurðsson, 2008; Sportiche et al., 2013), and not only the special null case it is commonly said to possess. The constraints associated with control structures change depending on the language in use as well.

How can a single null DP hope to take on such a large variety of characteristics and only at appropriate times based on the language in use? One idea to consider is that PRO is not actually a DP but a clause. The effects of reactivation that I have found support the idea that PRO reactivates the entire matrix clause during processing. The matrix clause is then copied into the subordinate clause and rewritten as the continued sentence is processed. Information is thus added and revised for the subordinate clause.

This new concept of PRO takes into account the effects of reactivation found in the pilot study at position three as well. Both possible antecedents would remain activated at the end of the sentence due to the clause reactivation. Table 4.7 in Chapter 4 shows that there is not a large difference in mean RT between the effects of syntactic priming in position three for subject and object control. The interaction plots in Table 4.8, however, show that position three is around 25ms slower in subject control constructions. The faster mean RT for object control could be due to recency effects, if the object NP of the matrix clause was the most recent to be considered during the overwriting process. Even though the matrix subject NP would be retained as PRO in a subject control sentence, it takes longer to reactivate in position three because the overwriting process continues after the selection of the subject NP.

Considering PRO as a clause can also explain the faster mean RT for subject control in position one and two. If the matrix clause is activated at the PRO position, the matrix subject would be the closest possible antecedent and is quickly reactivated. The position of PRO as position two within the syntactic structure of a control sentence further supports this theory of control.

This clausal analysis of PRO would explain the way that PRO receives case and how its characteristics deviate across languages. PRO is not considered an exact copy of its antecedent, like traces are of their referents, and a copy and rewrite strategy to co-referent assignment easily explains this characteristic of PRO. Though PRO is dependent on its antecedent NP in order to acquire a clausal copy, the semantic properties of the copied NP can be rewritten; hence, the copy's ability to obtain a new theta role.

The universal theory of control that I have presented in this section is in its very beginning stages of formation. Further experimental work is necessary to support the concept of PRO as a clause instead of a DP. Of particular interest would be the processing of PRO when it comes at the beginning of a sentence. How the copy and rewrite process would work in these constructions is unclear, but future experimental work should consider the possibility.

6.5 A Procedural Versus a Structural Account

The analysis of control given in this thesis is based on a structural account of language processing. This account is based on grammars that give a framework and rules for how language should be organized and produced. For example, phrase structure rules were introduced as a means to produce grammatical and limit ungrammatical sentences (Chomsky, 1957). Under this view of processing, sentence structure templates exist independently inside of our internal grammars and our words are mapped onto these templates to produce language.

On the other hand, there is another approach to sentence processing called the procedural account. This account of language processing has grown in popularity throughout the years as it is better able to account for certain complex sentence constructions and to reduce the overgeneration problems introduced by various structural models of grammar. Grammatical categories and rules are seen as objects that are associated with sets of properties. These properties constrain the ways in which these objects can be combined in a process called unification (Daniel and James, 2000).

This procedural account incorporates the structural account of language processing and combines feature structures, the representation of object properties, with syntactic rules and computational operations to explain the process of language composition. The use of more complex constraints during sentence construction and processing (or prediction) is a possible explanation of the intricate factors interacting within control sentence structures. If each word contains a list of features that specify expected complements then we might consider the infinitive marker to include a control clause or PRO expectancy in its list. The antecedent reactivation recorded after the infinitive marker supports this idea.

Based on the data recorded from my experimental work, it seems that a procedural account of sentence processing could be the most accurate way to analyze the processing of control structures. Supplementary research is necessary to support this hypothesis further. Research on control is still in its beginning stages and has a long way to go before we can formulate an all-encompassing, competent theory of control.

Chapter 7

Conclusion

The experimental work presented in this thesis includes a pilot study and a main experiment with results that point in the same direction. The null hypotheses can be rejected, as both control and raising constructions displayed reactivation and priming effects. The results support the alternative hypotheses. Raising trace referents indicate reactivation before the infinitive marker and control PRO antecedents indicate reactivation after the infinitive marker.

The hypothesis that control and raising are processed in the same manner can be rejected as well. There were different effects of priming and position for these two phenomena. The hypothesis that can be rejected with the most confidence is that PRO is a normal NP-trace, as suggested by Hornstein (1999). The reactivation patterns found for control were not similar to those of raising found in my research or to those found for NP-traces in previous coreference research.

As these are the first studies done on control and raising using this particular experimental design, there are inherent insecurities. The replication of results across the pilot study and main experiment in this thesis shows that these are reliable effects. Still, these effects need to be replicated in more experimental work and across various languages.

7.1 Future Research

The discussion chapter of this thesis suggested some ideas for future research on control. I will reintroduce these suggestions here and include more possible projects. As research on control is generally in its beginning stages, there is an overwhelming amount of research to be done. The list provided in this section is far from an exhaustive one.

Future research can include experiments testing a greater variety of control constructions. In my experiments, I focused on obligatory control represented by a particular sentence structure type. It would be interesting to compare the coreference process in control sentences that contain PRO before the introduction of its antecedent. There is also the possibility to test differences in processing when it comes to obligatory, optional, and arbitrary control.

The positions tested in my research have led to the conclusion that an infinitive marker might be a necessary component in the reactivation of a PRO antecedent. To test this hypothesis, research can be done on languages that have control constructions that do not contain an infinitive marker. Does antecedent reactivation still occur in the same position or is it delayed?

Further experimentation is necessary in order to understand the effects of written and spoken language on control processing. Does one mode lead to a speedup in coreference processing? Context might cause a difference in processing as well.

One major research project that will lead to a better understanding of the universality of control is one that compares the processing of this phenomenon across languages. Control is assumed to be part of universal grammar and has therefore been squeezed to fit in a box applicable to all languages. It is possible that control is not a universal phenomenon after all. It must be tested and compared in various languages in order to consider this possibility.

The universality of control can be tested using second language speakers as well. If control is processed in a similar manner by a native speaker and a second language speaker of a language then it is likely to be a part of universal grammar. This would support the idea that control is the same phenomenon in all languages.

7.2 Final Remarks

Current major theories of control have yet to explain how the characteristics of PRO seem to be language dependent or how control is processed in relation to other coreference phenomena. The PRO Theorem is the closest to a universal theory of control in literature today; nonetheless, we know that it is incompatible with data recorded on control structures in other languages. More recent research on control has attempted comparisons to similar syntactic processes involving trace positions in hopes of finding a way to categorize it in a preexisting syntactic category. Researchers have yet to be successful in this feat. The processing of control remains mysterious.

The significant effects of priming and position found in my experimental work provide a small window into the complex process of control. The results discussed in this thesis lead to even more possible theoretical hypotheses. Further research is necessary to advance our understanding of the representation and processing of control. Researchers still have a long way to go before we can say that we are PROs on the topic of control.

Appendix A

Pilot and Main Experiment Test Sentences

Pilot Study:

Subject Control

1) Sjiraffen tilbød alligatoren å finne mat.

2) Siraffen lærte av elefanten å drikke fra elva.

3) Alligatoren lovet sjiraffen å bade i sjøen snart.

4) Alligatoren skyldte flodhesten å lage lunsj.

Object Control

1) Flodhesten frarådet alligatoren å gå til festen.

2) Elefanten tillot sjiraffen å danse for barna.

3) Flodhesten nektet elefanten å spise bananer til middag.

4) Elefanten anbefalte flodhesten å ta et bad før sengetid.

Filler (Non-control) Sentences

1) Flodhesten gikk med elefanten til konserten i går.

2) Elefantens venn, alligatoren, fikk en stor gave til jul.

3) Sjiaffen og flodhesten sprang et løp i kveld.

4) Alligatoren bet sjiraffen på nesen på mandag.

Main Experiment:

Subject (2) Control

1) Apekatten lover elefanten å bade i sjøen snart.

2) Sjiraffen tilbyr alligatoren å ta ansvar for sine feil.

3) Elefanten skylder sjiraffen å lage lunsj til dem begge.

4) Alligatoren blir bedt av apekatten å være en god venn.

Subject (1) Control

1) Apekatten lærer å sprute vann ut av nesen.

2) Sjiraffen ønsker å gå hjem så snart som mulig.

3) Elefanten klarer å finne mat til frokost.

4) Alligatoren forsøker å bli full på råtne bananer.

Object Control

1) Elefanten tillater sjiraffen å plukke blomster i hagen.

2) Apekatten nekter elefanten å hente noe mat til middagen.

3) Sjiraffen anbefaler alligatoren a ta et bad før sengetid.

4) Alligatoren fraråder apekatten å spise mat for sent.

Subject-to-subject Raising

1) Alligatoren synes å fange fisk til frokost hver dag.

2) Apekatten tenderer å klatre i tre for moro skyld.

3) Elefanten begynner å spise bananer til jul.

4) Sjiraffen slutter å invitere elefanten på middag.

Subject-to-object Raising

1) Sjøen anser sjiraffen å ha for mange bølger.

2) Bananen antar apekatten å være god til middag.

3) Blader erklærer elefanten å være veldig nyttig til tørking.

4) Båten forstår alligatoren å være full av mat.

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