This paper reports the results of an experiment designed to adjudicate between two theoretical accounts of de re/de dicto ambiguity: the scope account (Montague 1973; Russell 1905) and the world variable binding account (Percus 2000; von Fintel & Heim 2011). The results are partly compatible with the scope account and completely incompatible with the world variable account, thus seeming to favour the former. This conclusion is not without complications, and I suggest there are two potential sources for the problematic results: a learning effect or a lexical surprisal effect. Once we take these factors into consideration, the observed incompatibility may not be as problematic as first thought.

1. Introduction

This paper presents results from a self-paced reading study which sets out to provide experimental evidence that could distinguish between two theoretical accounts for deriving de re/de dicto ambiguities: the traditional scope account and the world variable binding account. One major difference between these two accounts is the presence of covert movement in the former, and the absence of covert movement in the latter, in deriving a de re interpretation. Using the ACD (Antecedent Contained Deletion) paradigm of Hackl et al. (2012) to assess whether covert movement occurs in online sentence comprehension, the experiment presented here compares the processing cost of ACD under a de re biased context to the processing cost of ACD with a non-biased context, in order to see whether contextual bias for a de re reading has any effect on the processing time of ACD. If covert movement occurs in online structure building, then ACD processing will be facilitated, thus providing evidence for the scope account, and if ACD is not affected, this would then indicate that covert movement has not taken place, thus providing evidence for the world variable binding account. The results presented here appear to be completely incompatible with the world variable account, and only partially compatible with the scope account. I suggest that what complicates the compatibility of the results with the scope account could be due to one of two factors, namely, a potential learning effect or a surprisal effect, both of which, when controlled for in further research, may lead to results which are in
fact compatible with the scope account.

2. De Re/De Dicto Ambiguity

It is a well known property of intensional predicates (e.g. modals, propositional attitudes) that they give rise to an ambiguity regarding the DP embedded in their clausal complements (Chierchia & McConnell-Ginet 2000; McKay & Nelson 2010; Gamut 1991; von Fintel & Heim 2011; Quine 1956), known as the de re/de dicto distinction.\(^1\) For illustration, take the example sentence in (1) which could be uttered in two different contexts ((1a) and (1c)) and give rise to two distinct interpretations for the same surface string of words.

(1) John was willing \(_{TP}\) to read \([\text{DP} \text{ every } \text{NP} \text{ book that Mary bought }]\]

a. **Context:** John knows that Mary has good taste in literature and that she recently bought some books for her collection. John doesn’t know which books she bought but he was willing to read whichever ones she did buy.

b. **De Dicto:** All the books that John was willing to read are whichever ones Mary bought.

c. **Context:** John is a big fan of H.G. Wells and was therefore willing to read *The Time Machine, War of the Worlds*, and *The Invisible Man*. Unbeknownst to John, Mary likes collecting late 19\(^{th}\) century science fiction and bought those same books.

d. **De Re:** All the books that John was willing to read just happen to be the same ones that Mary bought.

We see here that the DP *every book that Mary bought* is embedded under the propositional attitude predicate *was willing* and gives rise to two interpretations of the sentence. Under the de dicto interpretation (1b), the books that John was willing to read seem to depend on whatever books Mary bought. The description *every book that Mary read* is integral to what John’s willingness is about. So, if Mary bought *Dune, Solaris*, and *Neuromancer*, then John was willing to read those books. If on the other hand Mary bought *The Time Machine, War of the Worlds*, and *The Invisible Man* then those are the books that John was willing to read. Under the de re interpretation (1d), John’s willingness is about a particular set of books, in this case, *The Time Machine, War of the Worlds*, and *The Invisible Man*, and it just so happens that this set of books is the same as the set of books Mary bought. If asked what books he was willing to read, John would not use the description *every book that Mary bought* since he is unaware of the books she bought and thus this description is not integral to what John’s willingness is about.

One way of typically distinguishing a de re reading from a de dicto reading semantically is to look at the preservation of truth under substitution of a co-designating term as in (2).

(2) Semantically de re/de dicto (McKay & Nelson 2010):

A sentence is semantically de re just in case it permits substitution of co-designating terms salva veritate. Otherwise, it is semantically de dicto.

\(^1\)More specifically, the ambiguity arises with regard to the restrictor of the DP, as we will see in Section 2.1. For introductory explanatory purposes in this section I will just make reference to the DP.
For the context in (1a), if we tried to substitute the DP every book that Mary bought in (1) with another DP that denoted the same set of books, e.g. the books by H.G. Wells assuming that the set of books Mary bought was The Time Machine, War of the Worlds, and The Invisible Man, the reading in this context would no longer be true, since the description every book that Mary bought is integral to what John was willing to read, thus indicating a de dicto reading. On the other hand, for the context in (1c), we can substitute the DP every book that Mary read in (1) with another DP denoting the same set of books. For example, if the speaker instead uttered: John was willing to read [DP the books by H.G. Wells] in this context then the sentence would still be true, thereby indicating a de re reading.

2.1. Theoretical Approaches: Possible Worlds

This section addresses two main theoretical approaches for deriving the distinction between de re and de dicto interpretations, assuming that the distinction between the two readings is one of a difference in the world of evaluation of the DP restrictor, and that propositional attitude predicates are analyzed as intentional/modal operators. The de re interpretation would arise when the DP restrictor is evaluated in the actual world, whereas the de dicto reading would arise when it is evaluated in every possible world made accessible by the intensional operator. If we were to represent the paraphrases in (1b) and (1d) in terms of their truth conditions with regard to possible worlds, the distinction would be as in (3).

\[(3)\]
\[a.\] De dicto: Every possible world in which John’s willingness is realized\(^2\) is a world in which he reads every book that Mary bought, in that world.
\[b.\] \(\forall w \in \text{Acc} \forall x [\text{book}(x) \in w \land \text{bought}(m,x) \in w \rightarrow \text{read}(j,x) \in w]\)
\[c.\] De re: Every book Mary bought in the actual world is such that in every world where John’s willingness is realized, he read them.
\[d.\] \(\forall x [\text{book}(x) \in w_o \land \text{bought}(m,x) \in w_o \rightarrow \forall w \in \text{Acc} [\text{read}(j,x) \in w]]\)

For the de dicto reading we obtain a scenario where every book John was willing to read can vary depending on each possible willingness world of John’s, and for the de re reading the situation is one where every book John was willing to read does not vary depending on each of John’s willingness worlds, it is the same set of books in all of them, i.e. those Mary bought in the actual world.

2.1.1. Scope Account

How can this distinction between evaluation worlds be captured? One account determines the relevant evaluation world by the LF position of the DP. This is the scope account of Russell (1905) and Montague (1973) where de re/de dicto ambiguity is an instance of scope ambiguity. In order for the restrictor/NP to be evaluated in the actual world (and derive a de re reading) it must be outside the scope of the intensional operator, since all predicates that occur within the scope of an intensional operator must be evaluated in the same possible worlds made accessible

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\(^2\)I.e. for every possible world which is an element of the set of accessible worlds (Acc).
by that operator. Thus, the only way to be evaluated in the actual world is to not be in the scope of the intensional operator. To do this, the whole DP is assumed to move covertly to adjoin to the nearest position where it is outside the scope of the intensional operator. To derive the de dicto reading the DP remains in situ\(^3\). Schematically, following Keshet (2008, 2010), the resulting LFs for each reading would be as in (4).

\[(4) \text{ For an intensional operator } \alpha:\]
\[a. \quad [\ldots \alpha [\ldots [DP \ D NP ]]\]
\[b. \quad [[[DP \ D NP ]_1 \ldots \alpha [\ldots t_1]]\]

2.1.2. World Variable Account

In the world variable account of Percus (2000); von Fintel & Heim (2011), the relevant evaluation world is determined by the introduction of overt world variables associated with the DP restrictor in the LF syntax and the operators which bind them. As we can see in the LFs in (5), there are overt world variables\(^4\) and \(\lambda\)-operators which bind these variables to determine the world where each predicate is evaluated.

\[(5) \text{ For an intensional operator } \alpha:\]
\[a. \quad [\lambda w_o \ldots \alpha [\lambda w_1 \ldots [DP \ D NP w_1]]]\]
\[b. \quad [\lambda w_o \ldots \alpha [\lambda w_1 \ldots [DP \ D NP w_o]]]\]

The de dicto reading follows from an LF where the world variable of the DP restrictor is bound by the \(\lambda\)-operator of the embedded clause and the de re reading follows from an LF where the world variable of the DP restrictor is bound by the \(\lambda\)-operator of the matrix clause\(^5\).

\[3^\text{While the DP remaining in situ would be the case for definite DPs, if the DP is quantificational on the other hand, QR of that DP would still have to be assumed to resolve the type mismatch of a QDP in object position, but crucially this QR would move to a position still within the scope of the intensional operator, (i). A de re reading with a QDP would be derived in the same way as with a definite DP, (ii).}

\[4^\text{World variables are assumed to be generated as sisters to all lexical predicates. For getting the de re/de dicto distinction here we are concerned with the world variables that are sisters to the DP restrictor, e.g. as a sister to the NP.}

\[5^\text{In (5), the DP remains in situ, which would be the case if the DP was non quantificational. If on the other hand the DP was quantificational, QR to resolve the type mismatch would be needed. QR targets the most local clausal node and the QDP in both (i) and (ii) below would adjoin to the embedded TP. Note that this position in both cases is below the intensional operator, thus the de re/de dicto distinction is coming not from the scope of the DP but from the binding of world variables, as in (i) and (ii) below.}

(i) \quad [\lambda w_o \text{ John wants } [\lambda w_1 \text{ [a book} w_1 \text{ ]} 2 \text{ [PRO to read } t_2 \text{]]}]\]
(ii) \quad [\lambda w_o \text{ John wants } [\lambda w_1 \text{ [a book} w_o \text{ ]} 2 \text{ [PRO to read } t_2 \text{]]}]\]
At this point, both accounts are successful in capturing the differences in evaluation worlds in order to derive a de re or de dicto reading. So, with regard to these basic examples, both accounts are on equal footing. Furthermore, as pointed out by Keshet (2010), there is other data beyond these basic cases showing that one account still does not seem preferred over the other. In brief, he shows that the scope account undergenerates, whereas the world variable account overgenerates.

This is where experimental evidence could prove useful in adjudicating between the two accounts. While both accounts derive the de re/de dicto distinction in terms of different worlds of evaluation, they do so with different theoretically assumed mechanisms. In order to derive a de re reading, the scope account uses covert movement, whereas the world variable account does not, and instead uses variable binding. The research presented here attempts to find experimental evidence for the use of these mechanisms in online LF structure building. Since the key distinguishing factor between these two accounts is movement versus no movement in the derivation of de re interpretations, the experimental question is reduced to whether or not there is processing evidence for covert movement in the real time comprehension of de re interpreted sentences.

3. Processing Covert Movement: ACD Paradigm

Much recent experimental work by Martin Hackl and colleagues has addressed the question of whether there is processing evidence for covert movement, i.e. quantifier raising (QR), in online LF structure building (Hackl et al. 2012; Breakstone et al. 2011; Hackl et al. 2009; Varvoutis & Hackl 2006). Using self-paced reading methodology, an experimental paradigm was created that evaluates the processing time of ACD hosted in a DP to see if QR of that DP has occurred in online LF structure building.

Hackl et al. (2012) measured the processing time of ACD hosted in a quantified DP compared to ACD hosted in a definite DP and used their experimental findings contribute to the debate between type shifting (Jacobson 1998, 2008) versus QR approaches (Heim & Kratzer 1998) for resolving the type mismatch that arises with QDPs in object position. Hackl et al. (2012) found that processing ACD hosted in a QDP is quicker than processing ACD hosted in a definite DP, which they argue is evidence for the QR approach. This paradigm hinges on how ACD is assumed to be resolved in theory and in processing, which the next section will outline.

3.1. Antecedent Contained Deletion

ACD is a type of verb phrase ellipsis where the elided VP is embedded in a relative clause which modifies the direct object of the sentence. Given the surface structure of the sentence, the elided VP also seems to be contained inside the VP that acts as its antecedent, as in (6).

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The size of the ellipsis can also vary. For example, in local ACD (ia), the elided VP *read* seems to be contained in the embedded VP that acts as its antecedent. On the other hand, in non-local ACD (ib), the elided VP *willing to read* seems to be contained inside the larger matrix VP that acts as its antecedent.
(6) John \[ V_P \text{read every book that Mary did } [V_P \text{read}] \]

This is problematic for theories of VP ellipsis that require an identity (or parallelism) condition to be satisfied between the elided VP and its antecedent (Bouton 1970; Sag 1976) since identity requires that, in order for the VP to be deleted, it must have an identical/parallel syntactic structure to its antecedent. If the elided VP is contained inside its antecedent then it is impossible for the two VPs to be structurally identical.

In order to resolve this problem, the standard analysis for ACD involves covert movement of the DP containing the elided VP to the closest clausal position where it is external to the antecedent VP (Sag 1976; May 1985), as in (7).

(7)

\[
\begin{array}{c}
\text{TP} \\
\downarrow \text{I} \\
\text{TP} \\
\downarrow \text{DP} \\
\text{every book } [C_P \text{op}_2 \text{that Mary did } [V_P \text{read}]] \\
\end{array}
\]

Note that for local and non-local ACD the landing site of QR to resolve antecedent containment will differ. For local ACD the DP will QR to adjoin to the embedded TP as in (7), whereas for non local ACD the DP will adjoin to the matrix TP, as in (8).

(8)

\[
\begin{array}{c}
\text{TP} \\
\downarrow \text{I} \\
\text{TP} \\
\downarrow \text{DP} \\
\text{every book } [ \text{op}_2 \text{that Mary was willing to read } t_2] \\
\end{array}
\]

(i) a. John was willing to \[ V_P \text{read every book that Mary did } [V_P \text{read}] \]

b. John was \[ V_P \text{willing to read every book that Mary was willing to read } t_1 \].
Lastly, if ACD resolution proceeds along these lines in processing, the parser will minimally have two operations to perform: First, QR of the DP to a position where it is no longer inside the VP that acts as the antecedent to ellipsis and second, the establishment of an anaphoric dependency between the elided material and its antecedent.

3.2. Processing Evidence for Covert Movement

Assuming this analysis of ACD, Hackl et al. (2012) predict that the type of DP that ACD is hosted in will have an effect on the processing time of ACD, but only under the QR account and not the type shifting account. These predictions follow from the left to right nature of sentence processing and the number of operations that are assumed the parser must carry out when it encounters the quantifier or definite article and again at the following ACD site.

It the garden path model of sentence processing (Frazier 1978), it is assumed that the parser proceeds along various economy principles (such as minimal attachment and late closure), and will build the simplest syntactic structure possible and try to integrate each word it comes across into the current syntactic structure it is building. If it cannot integrate a word into the syntactic structure, then that structure undergoes reanalysis so that integration can occur. Under the QR approach to QDP integration (Heim & Kratzer 1998), they predict that when the parser encounters the QDP, it cannot integrate it into the syntactic structure for semantic type reasons and must therefore reanalyze the current syntactic structure it is building into one where the QDP has undergone QR to adjoin to the most local clausal node. Continuing left to right, the parser then encounters the ACD site, and, all things being equal, the parser should have two operations to perform: 1) resolving antecedent containment 2) an operation linking the elided material to its antecedent. But, because of the prior QR of the DP, the number of operations the parser has to perform is reduced to one.

Facilitation in ACD processing will occur only when the DP is quantificational because it has already QR-ed the DP for type reasons to a position which also happens to coincide with the position that the DP would need to QR to for the resolution of antecedent containment. For definite DPs this facilitation would not occur because there is no type mismatch with a definite DP in object position, hence no motivation to do QR prior to encountering the ACD site. Basically, for QDPs and definite DPs, the final syntactic structures the parser builds are the same (see (7)), but the time-course differs depending on the type of DP the ellipsis is hosted in.

For the type-shifting account, no facilitation would be predicted, regardless of the type of DP. When the parser encounters the QDP, it resolves the type mismatch by leaving the DP in situ, which means that when ACD is encountered the standard two processing operations needed to resolve ACD would be carried out. Similarly, since there is no type mismatch with a definite DP, the processing operations at the ACD site would be the same under this account, thus predicting no difference in the processing time of ACD.

Turning to the results of the experiment run by Hackl et al. (2012) (Figure 1), there was a significant main effect of ellipsis (F(1,43) = 5.619; p < 0.05) and a significant interaction effect (F(1,43) = 7.987; p < 0.017) indicating that the processing cost of ACD was quicker when it was hosted in a QDP compared to when it was hosted in a definite DP. Hackl et al. (2012) argue that these results only follow if the DP hosting ACD had undergone prior QR, thus concluding
that there is processing evidence for covert movement in the grammar.

Figure 1: Hackl et al. (2012) Experiment 1 Residual RTs three words after V/Aux (n=44)

4. Current Study

The current study uses the ACD paradigm of Hackl et al. (2012) to test whether or not covert movement has occurred in constructions where the restrictor of the DP is obligatorily interpreted as de re. The basic idea is that if the parser proceeds along the lines of the scope account when it encounters a DP restrictor which must be interpreted de re, then QR to a position above the intensional operator will occur, which would reduce the processing time of ACD downstream. On the other hand, if the parser proceeds along the lines of the world variable account, then the processing time of downstream ACD should not be affected.

4.1. Processing Assumptions

The main concern regarding how sentence processing proceeds here is how LF representations are built, or in other words, how interpretations are associated with sentences as they are perceived, word by word, online. First, I will assume that LF representations are built in tandem with PF representations, such that, as PF representations are incrementally being built, these syntactic structures are also incrementally being interpreted.

Second, I also assume that the parser prefers to build LF representations according to various economy principles. In general, that online sentence processing proceeds along principles of economy is widely accepted. In the syntactic processing literature there is a considerable amount of research claiming that the construction of surface structure representations is guided by structural economy principles, such as Frazier (1978)’s minimal attachment and late closure. Thus, I will assume that the construction of LF representations is similarly guided by principles of economy. What is the precise definition of this notion of economy with regard to LF struc-
ture building? One suggestion is that of Tunstall (1998), who proposes that the parser prefers to build the LF that deviates the least from the PF representation. Taking this idea, I assume that, by default, when the parser encounters a word, it will attempt to integrate it into an LF representation in the same way as it would for the PF representation. If this integration is not possible, for example, if a type mismatch occurs, then the LF structure being built will undergo reanalysis, which will incur some processing cost.

Lastly, I will also assume that LF structure building takes discourse context into consideration, such that, if the parse first built according to economy principles is inconsistent with contextual information, reanalysis of the LF being built will occur so that the interpretation of the structure is one consistent with the discourse context. That processing takes contextual information into consideration is a standard assumption in context sensitive processing models such as that of Altmann & Steedman (1988), and I adopt this notion of sentence processing being sensitive to context, while not necessarily committing to other aspects of their model.

In sum, I assume that the construction of LF representations is sensitive to discourse context, and is incrementally built alongside PF representations with similar syntactic structures by default. But reanalysis of this initial structure can occur when the interpretation of this structure cannot proceed or if the interpretation is not consistent with contextual information. Reanalysis can occur therefore when there is a type mismatch, or if the resulting interpretation of the structure is inconsistent with information established in the discourse context. This reanalysis of the LF structure is assumed to be costly and should result in an increase in observed reading times.

4.2. Design

The aim of the current study is to see if a bias for a de re reading affects the processing cost of ACD hosted in a QDP\(^7\). In other words, it aims to see whether there is a difference in the processing cost of ACD when preceded by a de re biased context compared to a non-biased context. As such, the experiment was a 2x2 design, crossing ellipsis (± ACD) and contextual bias (± Bias), as in (9).

\[(9)\]

\[
\begin{array}{c|cc}
 & -ACD & +ACD \\
- Bias & A & B \\
+ Bias & C & D \\
\end{array}
\]

The –ACD conditions act as a baseline to the +ACD conditions in order to first assess the processing cost of ACD. The idea is to take sentences with non-local ACD\(^8\), as in (10a), and

\(^7\)A second experiment was also run to test the same thing but for definite DPs in order to see if the effects can be attributed to processing de re interpretations and not just an effect of the type of determiner. The results of this experiment have been difficult to interpret, visual inspection shows that definite DPs do pattern like QDPs, but statistical analysis has not given significant results. For this reason, as well as space considerations, I have excluded the results of this second experiment from the discussion here.

\(^8\)The use of non-local ACD is crucial here since it is only in these ACD constructions that the landing site for
look at the difference between the reading times at the ACD site and the reading times at the verb site in sentences such as (10b), to assess the processing cost of ACD.

(10) a. John was willing to read every book that Mary was willing to read.
    b. John was willing to read every book that Mary bought.

Each of the sentences in (10) would also be preceded by a context that was either biased for a de re reading, or interpretation-neutral. The intention then would be that the −Bias conditions act as a baseline to the +Bias conditions to see whether contextual bias affects the processing cost of ACD. So basically, the experiment compares (A − B) to (C − D) for any differences in reading times.

4.3. Predictions

For the two theories under consideration here there are two very different sets of predictions with regard to what is expected to happen in terms of processing at the V/Aux site when the sentence is biased for a de re interpretation compared to when it is not.

4.3.1. Scope Account

For the scope account, an interaction effect is predicted with regard to reading times at the V/Aux site, as shown in Figure 2. To see why, consider the number of operations that the parser would have to perform here for each of the four conditions, (11).

Figure 2: Predicted RTs for processing ACD under the scope account: −BIAS > +BIAS

resolving antecedent containment coincides with the position that the DP would be required to be in for interpreting the sentence de re, according to the scope account.
Deriving De Re/De Dicto Interpretations in Online Sentence Processing

(11) Parsing operations/condition at the V/Aux site:

a. \( -\text{BIAS} - \text{ACD} \): no movement at the verb site, integrate the verb into syntactic structure currently being built
b. \( -\text{BIAS} + \text{ACD} \): QR where Q/DP is integrated as adjoined to the matrix TP, resolution of anaphoric dependency
c. \( +\text{BIAS} - \text{ACD} \): no movement at the verb site, integration of verb into current syntactic structure
d. \( +\text{BIAS} + \text{ACD} \): no movement, resolution of anaphoric dependency

For the \( -\text{BIAS} - \text{ACD} \) condition (11a), there is predicted to be no movement at the verb position in the relative clause. There is no contextual bias which would force movement of the DP prior to the ACD site or syntactic evidence for movement (the presence of ACD would be considered syntactic evidence which would force movement so that the elided VP is no longer contained within its antecedent VP). The verb is integrated into the syntactic structure currently being built in accordance with parsing economy conditions. Thus, no operations other than the default structure building operations are necessary.

In the \( -\text{Bias} + \text{ACD} \) condition (11b), when the ACD site is encountered there is syntactic evidence that structural reanalysis has to occur since the presence of the auxiliary was marks an ellipsis construction which can only be licit if the DP containing the elided VP QRs to a position where the elided VP is no longer contained within its antecedent VP. In addition there is also a dependency relationship which needs to be established between the elided VP and its antecedent. Thus, two operations occur.

In the case of the \( +\text{BIAS} - \text{ACD} \) condition, the LF structure building operations would be as in (11c). This condition has movement of the DP to adjoin to the matrix TP prior to the ellipsis site. The contextual bias for a de re interpretation motivates movement when the parser encounters the DP every book, which should be interpreted as having scope above the intensional predicate. Crucially, at the verb site, there is no movement necessary, and the verb is integrated into the syntactic structure currently being built.

For the \( +\text{Bias} + \text{ACD} \) condition, the LF structure building operations would be as in (11d), which involves movement of the DP to the matrix TP, similar to the \( -\text{Bias} + \text{ACD} \) condition. But, while the final LF is the same, the motivation and the time course for building this structure differs from the other \( +\text{ACD} \) condition. Whereas the \( -\text{Bias} + \text{ACD} \) condition has movement to the matrix TP at the ellipsis site which was motivated for syntactic reasons, this condition has motivation for movement prior to the ellipsis site due to the preceding biased context. Thus, the DP is reanalyzed as adjoined to the matrix TP when the parser encounters the DP every book, rather than at the ACD site. In terms of operations involved at the ACD site then, there would be no movement, but there would also have to be an operation which links the elided VP to its antecedent.

When comparing these operations between \( +\text{ACD} \) and \( -\text{ACD} \) conditions, the reading times in the \( -\text{Bias} + \text{ACD} \) condition should be slower than that of the \( -\text{Bias} - \text{ACD} \) condition because it requires two more operations at the ACD site. On the other hand the reading times for the \( +\text{Bias} + \text{ACD} \) condition should be around the same as that for the \( +\text{Bias} - \text{ACD} \) condition since both conditions involve no movement and the integration of the V/Aux into the current syntactic structure. Furthermore, when the differences between the \( +\text{Bias} \) and the \( -\text{Bias} \) conditions are
compared, the prediction is that the difference between the −Bias conditions should be greater than the difference between the +Bias conditions, thus predicting an interaction effect.

4.3.2. World Variable Account

For the world variable account (Percus 2000; von Fintel & Heim 2011), a main effect of ellipsis is predicted at the V/Aux site, as shown in Figure 3, given the number of operations that the parser would have to perform at this region for each of the four conditions, (12).

(12) Parsing operations/condition at the V/Aux site:⁹

a. −Bias−ACD: no movement at the verb site, integrate the verb into syntactic structure it’s currently building
b. −Bias+ACD: QR where Q/DP is integrated as adjoined to the matrix TP, resolution of anaphoric dependency
c. +Bias−ACD: same as (12a)
d. +Bias+ACD: same as (12b)

Figure 3: Predicted RTs for processing ACD under the world variable account: −BIAS ≈ +BIAS

For the −Bias−ACD condition (12a), when the parser encounters the verb, there is no movement required and it integrates the verb into the syntactic structure that is currently being built, according to parsing economy requirements. There is no motivation from the preceding context or from syntactic requirements to do any operations other than the default structure building operations.

⁹Binding of a world variable would presumably happen when the parser encounters the NP, a dependency between the appropriate operator and the variable is established. For the processes under consideration here, this binding would not happen at the ACD site, but at some point earlier in the time course of the sentence.
For the −Bias+ACD condition, (12b), there is movement of the DP to adjoin to the matrix TP. When the ACD site is encountered there is syntactic evidence that structural reanalysis has to occur since the presence of the auxiliary was marks an ellipsis construction which needs to be resolved by moving the constituent containing the elided VP to a position in which it is no longer contained inside its antecedent. Thus the number of operations in this condition compared to the −Bias−ACD condition is greater.

In the case of the +Bias−ACD condition (12c), there is no movement required at verb site since there is no ellipsis in this condition which would force movement. The verb would thus be integrated into the syntactic structure currently being built. The prior context specifies that the NP should be interpreted de re, and therefore the world variable is bound by the actual world operator, but this binding operation would not happen at the verb site. In sum, this condition would be processed similarly to the −Bias−ACD condition and requires only the default structure building operations to occur at the verb site.

Lastly, for the +Bias+ACD condition (12d), there would be movement of the DP to adjoin to the matrix TP. This movement would happen when the parser encounters the auxiliary was and the motivation for movement in this condition comes from the need to resolve the problem of antecedent containment. In contrast to the scope account, the interpretation requirement that the NP be evaluated in the actual world does not require any movement of the DP. Thus, prior to the ellipsis site there is no motivation to move the DP. When the parser encounters the ellipsis site the number of operations that occur at this point in time are greater than those predicted to occur in the +Bias−ACD condition.

Therefore, I predict that the +ACD conditions, regardless of the presence or absence of bias should take longer to process than the −ACD (verb) conditions. Thus, when comparing the differences between the +ACD and the −ACD conditions (i.e. the processing cost of ACD) under a biasing and a non-biasing context, there should be no difference between +Bias and −Bias conditions, as shown in Figure 3.

4.4. Methods

4.4.1. Participants

Twenty-six participants were recruited through the McGill Linguistics Department’s Prosody Lab and a McGill introductory course in Linguistics and were all adult native speakers of English. Participants were tested in the Prosody Lab using the Linger software (version 2.94 developed by Doug Rohde) which was installed and run on a Mac computer. All subjects were compensated for their participation, receiving $10.00.

4.4.2. Stimuli

Twenty experimental items were constructed according to the format in (13). They consisted of a brief context that was either biased towards a de re reading or neutral towards a de re or de dicto reading for a subsequent sentence. Each sentence that followed the context consisted of a matrix modal predicate (either a deontic, epistemic or propositional attitude predicate), that takes as its complement an embedded clause with a quantificational object DP containing
a relative clause with ACD or a relative clause without ACD. The \(-ACD\) sentences had a lexical verb in the place where the \(+ACD\) sentences had the auxiliary verb \(\text{was}\). The verbs that were used in the relative clauses in the \(-ACD\) conditions were all different from the verbs that occurred previously in the sentence.

Biasing contexts were constructed so that only a de re reading should be inferred from the context, and used a variant of the ‘just so happens’ paraphrase, which excludes a de dicto reading, thus making the de re reading the only one compatible with the context (13a). Non-biased contexts were created to be relevant to the following sentence, but neutral with regard to a de re or de dicto interpretation. Contexts were created so that they did not contain any information from which a de re or de dicto interpretation could be inferred (13b).

(13) a. **Biasing Context**: A violinist was deciding which songs she will play from a list during her rehearsal and was reluctant to play the 1812 Overture, Bolero, and the Blue Danube Waltz. It turns out that a talented flautist heard/was reluctant to play these exact same songs earlier during a rehearsal, but the violinist didn’t know this. Therefore, …
   (i) the violinist was reluctant to play \([DP\) every song that the talented flautist \(\text{heard}\)]
   (ii) the violinist was reluctant to play \([DP\) every song that the talented flautist \(\text{was}\)]

b. **Non-Biasing Context**: A violinist in an orchestra had a rehearsal for an upcoming performance at the concert hall. A talented flautist who was also in the orchestra had to attend the same rehearsal. And, …
   (i) the violinist was reluctant to play \([DP\) every song that the talented flautist \(\text{heard}\)]
   (ii) the violinist was reluctant to play \([DP\) every song that the talented flautist \(\text{was}\)]

   … during her rehearsal at the concert-hall.

Each sentence in a template was followed up by a comprehension question of either the type in (14a) or (14b) which served the purpose of testing how participants were interpreting the sentence, as well as to ensure that the participants continued to pay attention to the sentences that they were reading.

(14) **Comprehension Questions**:
   a. Was the violinist reluctant to play the songs because the flautist was reluctant to play/heard them?
   b. Was it just a coincidence that the violinist was reluctant to play the songs that the flautist was/heard?

Lastly, since the region of interest for this study is the V/Aux site and the three words after this position,\(^{10}\) all experimental sentences in the template had an adjunct clause following the

\(^{10}\)In previous studies using this paradigm, the facilitation effect of ACD was observed shortly after the V/Aux site, either two or three words after. Thus, if facilitation occurs in the current study, it will be at the same or similar region to these previous studies.
V/Aux site that was five to six words long so that any downstream effects from the processing of the verb or the ellipsis could potentially be observed. For all sentences in each template this adjunct clause was identical. In addition, adjectives modifying the subject of the relative clause were included to create more distance between the quantificational determiner so as not to run into any spill-over effects from the processing of these sentence elements into the V/Aux region. The adjective did not differ across the four sentences in a template.

4.4.3. Procedure

The experimental items were counterbalanced across four lists using a Latin-square design so that each participant saw only one condition from each item and that each item was tested the same number of times in each condition, thus making sure that items or participants did not contribute more to one level of the independent variables (±ACD, ±Bias) than another. In addition, to control for possible ordering effects, the presentation of experimental items in each list was randomized. Filler items were not used, so participants saw twenty experimental items in succession.

The experiment used masked self-paced reading methodology (Just et al. 1982) and each session started with instructions presented on the computer screen after which four practice items were presented. Two items were simple sentences and used as practice to familiarize participants with the moving window display, and the other two items were used as a warm-up and were similar to the experimental items in format and content, namely, they consisted of a context, followed by a target sentence, followed by a comprehension question. Participants were instructed to read the scenarios carefully and to take as much time as they wanted to fully understand the scenario before moving on. With regard to the target sentences, they were instructed to read at a natural pace but to also make sure they understood what they were reading.

4.5. Analysis

Comprehension questions were answered correctly 75% of the time across participants, and participants were excluded who did not answer questions correctly more than 65% of the time. Based on this percentage, only two participants were excluded. Residual reading times were then calculated in order to control for differences in word length between experimental items and also to control for individual differences in participants’ reading speeds. Further data were excluded from analysis where the comprehension question was answered incorrectly. Once the rRTs were calculated, z-scores for each rRT based on a given condition and word number were calculated. rRTs that had an absolute z-score of more than 2.5 were excluded from analysis. Lastly, a 2-way repeated measures ANOVA was conducted at the region of interest (V/Aux site +3).
4.6. Results

Visual inspection of the pattern of rRTs at the region of interest (Figure 4, starting at the V/Aux site and continuing up until three words after the V/Aux site) shows that the $-\text{ACD}$ conditions pattern in a similar way\textsuperscript{11}, and show similar increases and decreases in rRTs over the region. The $+\text{ACD}$ conditions also appear to pattern together.

This pattern seems to change upon visual inspection at the primary region of interest, V/Aux+3 (at the word rehearsal), where the rRTs for both $+\text{ACD}$ conditions decrease relative to the previous region. Whereas in the $-\text{ACD}$ conditions, the one that was preceded by a neutral context increases, while the one that was preceded by a biased context decreases. In addition, when comparing the rRTs of the $+\text{ACD}$ conditions relative to the verb conditions at this region, which given the experimental paradigm was necessary to assess the processing cost of ACD, the mean rRT for ACD with a biasing context is around the same as that for processing the verb. On the other hand, the mean rRT for processing ACD without a biasing context is quicker than the mean rRT for processing the verb. Thus indicating that the processing cost of ACD without a biasing context is quicker than with a biasing context. These differences between $-\text{ACD}$ and $+\text{ACD}$ conditions with a preceding biased or non-biased context are shown in Figure 5.

With regard to whether the observations from visual inspection are supported by statistical analysis, the results of the repeated measures ANOVA conducted on this region show that there

\textsuperscript{11}That is, despite the observed difference between rRTs for the $+\text{Bias}$ words which are overall quicker than the rRTs for $-\text{Bias}$ words, the general pattern of rRTs is similar for both $-\text{ACD}$ conditions.
is a significant main effect of ellipsis (F(1,23)=4.723, p<0.05) indicating that on average, the conditions with ACD had quicker rRTs than conditions without. There is also a main effect of bias (F(1,23)=15.769, p<0.05), but there was no significant interaction effect (F(1,23) = 2.382, p>0.05). Thus despite what visually looks like an interaction effect, it was not statistically significant.

5. Discussion

There are two main findings of the experiment addressed in this section with regard to the theoretical accounts outlined in Section 2.1. The first is the main effect of ellipsis, and the second is the apparent lack of interaction effect. Both findings are problematic for the theoretical accounts' predictions at first glance, but it seems that the problematic aspects of the results can be more easily reconciled with the scope account than they can with the world variable account.

As outlined in Section 4.3, there is a predicted interaction effect for the scope account, given the number of parsing operations that are assumed to occur at the region of interest, see (11). When comparing these operations between +ACD and −ACD conditions, the mean rRT for the −Bias+ACD condition should be slower than that of the −Bias−ACD condition because it requires two more operations at the ACD site. On the other hand, the reading times for the +Bias+ACD condition should be around the same as that for the +Bias−ACD condition since both conditions involve no movement and the integration of the V/Aux into the current syntactic structure. Furthermore, when the differences between the +Bias and the −Bias conditions are compared, the prediction is that the difference between the −Bias conditions should be greater than the difference between the +Bias conditions, thus predicting an interaction effect.

It is clear from Figure 5 that this is not realized. First, with a neutral context, ACD is processed quicker relative to the verb, which explains where the main effect of ellipsis originates. Note that the scope account would have been compatible with a main effect of ellipsis in addi-
tion to the interaction effect, but the direction of this effect would be predicted to be the opposite of what is observed here. We would expect that on average the rRTs for ACD should be slower relative to the verb not quicker. The second problem is that there is no significant interaction effect, which is not what the scope account predicts. Even if we were able to statistically support what visually looks like an interaction effect, there would still be a major problem for the scope account since the interaction effect would be in the wrong direction. The main source of this problem is the fact the $–$Bias$+$ACD condition is processed quicker than the $–$Bias$–$ACD condition.

The world variable account does not fare any better in terms of its predictions being realized. As outlined in Section 4.3 this account predicts a main effect of ellipsis only, given the number of operations the parser is assumed to carry out in each of the four conditions in (12) above. In contrast to the scope account, the $+$ACD conditions, regardless of the presence or absence of contextual bias, should take longer to process than the verb conditions. Thus, when comparing the differences between the $+$ACD and the $–$ACD conditions (i.e. the processing cost of ACD) under a biasing and a non-biasing context, there should be no difference in rRTs, and there should only be a main effect of ellipsis. Turning to the observed results we see that these predictions are not borne out. While there is a main effect of ellipsis, the direction of this effect is not as predicted since the expectation was that the rRTs for ACD would be slower relative to the verb, but the results show that ACD is quicker relative to the verb.

While it seems to be the case that neither the scope account nor the world variable account are totally compatible with the results, the situation may be slightly better for the scope account since there is one observation which is compatible with its predictions. Namely, in the presence of a de re biased context, this account predicts that the rRTs for ACD should be around the same as those for the verb, and this is in fact borne out in the results. On the other hand, the world variable account makes no such predictions with regards to the rRTs for ACD relative to the verb with a preceding de re biased context. A dependent means t-test was run on the $+$Bias$–$ACD and $+$Bias$+$ACD conditions and no significant difference was found ($t(23)=−0.192, p>0.05$), indicating that the means for these two conditions are not particularly different from each other, which is exactly what the scope account predicts.

What complicates the compatibility of the results with the scope account is what is observed when the context is interpretation-neutral. The question this result raises then, is why the mean rRT for ACD is quicker relative to the verb. As a first attempt, if we are already assuming that the reduced rRTs for ACD in the $+$Bias conditions are the result of prior QR, then it might be the case that the reduced rRTs for ACD in the $–$Bias conditions are also the result of prior QR. The task at hand now would be to explain why there might be prior QR in these non-biased contexts. One possible explanation relates to interpretation preferences. If participants have a preference for de re interpretations of DPs, regardless of contextual bias, then the parser would QR the DP to a position above the intentional predicated no matter what, therefore facilitating ACD in both $–$Bias and $+$Bias contexts.

There are two ways that this interpretation preference could arise. The first is that participants in general have a preference for de re interpretations, the second is that the preference was experimentally induced. With regard to the first, it seems unlikely that people in general have a preference for de re interpretations, given the results reported by Hackl et al. (2012), who found that in the absence of context, sentences nearly identical to those tested here had a mean rRT for
ACD that was significantly slower relative to the corresponding verb condition. The results in Figure 6 seem to reflect a default parsing strategy that builds the simplest syntactic structure first, i.e. one with no movement prior to the ACD site which, assuming the scope account, is a structure compatible with a de dicto interpretation. Then, when the parser does encounter the ACD site, it has to perform more operations to resolve ACD than if it had just encountered a verb, resulting in the observed increase in rRT for ACD compared to the verb. If people had a general preference for de re interpretations, this increase in rRT for ACD would not be expected to occur in the absence of context.

This leaves the other option of an experimentally induced interpretation preference. This is a possibility since no filler items were used in the experiment. Thus, the quicker rRTs for ACD in the −Bias conditions could be due to a learning effect of previously processing sentences which had to be interpreted de re. Indeed, looking at the scatter plots in Figure 7 of the rRTs at V/Aux+3 and the position of the item seen by the subject, we see that the rRTs for each condition decreased as the experiment progressed, and this relationship was significant in all conditions except the −ACD−Bias condition. Thus, a learning effect may be responsible for the quicker mean rRT for the +ACD−Bias condition.

On the other hand, while the rRTs did decrease over time for the +ACD−Bias condition, it is also possible that this decrease would not be enough to lower the predicted mean rRT as much as is actually observed. One crucial assumption with regard to this interpretation preference explanation of the data, is that the issue stems from the ACD conditions. Alternatively, instead of trying to explain why the ACD conditions may be quicker than expected, perhaps it is the verb conditions which are slower than expected. It has been suggested to me by Yosef Grodzinsky (p.c.) that the problem here may lie in the −ACD−Bias conditions and the processing of the verb in a non-biased context. If, for example, some of the verbs were unexpected, or not predictable in the neutral contexts, then encountering them would lead to a surprisal effect which

\[\text{Figure 6: Hackl et al. (2012) Experiment 2 rRTs three words after V/Aux (n=48)}\]

12To see this, compare the mean rRT for the every/verb condition in Figure 6 to the every/was condition.
would in turn result in an increase in rRTs at this region for this condition. The distribution of the rRTs for each item at V/Aux+3 for the $-ACD-$ Bias condition (Figure 8) show that some items do indeed have much slower rRTs than others and also that there is a lot of variability in the data for this condition. If these items with slower rRTs are not representative of standard verb processing, then they will inaccurately raise the mean rRT for this condition.

In sum, the results seem to be more compatible with the scope account given the fact that there was no significant difference in mean rRTs for processing the ACD condition compared to the verb condition under a biased context; a result predicted by the scope account but not the world variable account. One problem for the scope account though is the lack of interaction effect. This section addressed two possible explanations for this and, if either of these explanations is on the right track, then the observed incompatibility with the results may not be as problematic for the scope account as first thought.

6. Conclusions and Looking Ahead

At this point, there are certainly difficulties in concluding that the experimental results favour the scope account over the world variable account due to the lack of interaction effect that
was observed. The potential reasons suggested here for this lack of interaction effect can easily be controlled for in a follow-up experiment. First, to control for a potential learning effect, filler items can be used. Second, to control for a potential lexical surprisal effect, the non-biased contexts can be constructed so that the target verb is part of this preceding context. The expectation then, is that once these factors are controlled for, the results should coincide with the predictions of the scope account.

Lastly, there is one additional concern with the compatibility of the results with the scope account. Since the results of the experiment reported here only deal with QDPs, it would be necessary to show that definite DPs pattern in the same way as QDPs with regard to the processing of ACD in de re biased contexts. This would provide further support for the scope account, since under this account de re readings are derived via QR of the DP, regardless of the type of DP. It would thus be crucial to show that if an interaction effect is observed that it is the result of de re motivated covert movement as opposed to an effect of the DP being quantificational.

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