A new syntax for multiple *wh*-questions: Evidence from real time sentence processing*

Hadas Kotek & Martin Hackl, Massachusetts Institute of Technology

Current theories of interrogative syntax/semantics adopt two strategies for the interpretation of in-situ *wh*-phrases: *covert movement* and *in-situ interpretation*. The covert movement strategy is traditionally assumed to be all-or-nothing: the in-situ *wh*-phrase covertly moves to C or else stays in-situ and is interpreted in its base-generated position at LF. In this paper we argue that both traditional approaches to *wh*-in-situ cannot be maintained. We present evidence from real-time processing of English multiple *wh*-questions that in-situ *wh*-phrases require both covert movement and in-situ interpretation for their computation: an in-situ *wh*-phrase undergoes a short movement step, parallel to the behavior of traditional quantifiers, immediately upon integration into the structure. Following that step, the *wh*-phrase *can* but *need not* move any further: it can be interpreted in its landing site and make its contribution to interrogative semantics without any further movement. We propose the *partial movement* approach to *wh*-in-situ: A *wh*-phrase must be interpreted at a position with propositional type at LF—or *wh*-phrases in object position, this position is never the base-generated position and instead some covert movement is always required.

Keywords: multiple *wh*-questions, covert movement, in-situ *wh*-phrases, intervention effects, sentence processing

1 Introduction

In a language like English, the formation of a question involves at least two steps. First, a structure is formed in which a *wh-phrase* is produced in an argument position of a verb, (1a). Second, that *wh*-phrase is *overtly moved* to the left edge of the sentence, (1b). In a *multiple question* only one *wh*-phrase is pronounced at the left edge of the sentence, while the remaining *wh*-phrase(s) are pronounced in-situ, in, what appears to be, their base-generated positions, (1c).

(1) **Single and multiple questions**

a. Fred introduced which student to Mary?

b. Which student did Fred introduce __ to Mary?

c. Which student did Fred introduce __ to which professor?

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In the literature on the syntax and semantics of *wh*-questions, there are two schools of thought about the analysis of in-situ *wh*-phrases. Both approaches assume that *wh*-phrases are interpreted by an interrogative head C occurring at the left edge of the question at LF, but they differ in the mechanisms by which C is assumed to create interrogative meanings. Under the first of these approaches, all *wh*-phrases must be structurally adjacent to the C head that interprets them. This approach thus predicts covert movement of in-situ *wh*-phrases as a prerequisite for their interpretation. The second approach invokes mechanisms that interpret *wh*-phrases without any movement. Although these approaches differ substantially in their treatment of interrogative syntax and semantics, traditional means of investigation have not been successful in choosing a preferred account. In particular, these approaches differ in (a) how much covert movement they predict in the derivation of a multiple question, (b) what they assume could cause covert movement, and (c) what syntactic position is targeted by covert movement.

The goal of this paper is to investigate the possible position(s) of in-situ *wh*-phrases at LF. We will argue that both current approaches to *wh*-in-situ are insufficient to derive the correct syntax-semantics of *wh*-questions. We present the results of three self-paced reading experiments that show that the in-situ *wh* in English multiple questions minimally requires a short movement step, comparable to the behavior of quantifiers like *every*, but that from that point on *wh*-phrases can but need not move any further. These results are unpredicted by both approaches to in-situ *wh*-phrases, motivating a new proposal for interrogative syntax/semantics. Specifically, we argue that the results can be explained by a *partial movement* approach to *wh*-in-situ, but not under the traditional approaches.

The remainder of the paper is structured as follows. In section 2, we present the two traditional approaches to the interpretation of *wh*-in-situ and discuss the predictions these theories make regarding the source and extent of covert *wh*-movement in a multiple question. We also present the phenomenon of *Antecedent Contained Deletion* (ACD), which has been argued to require covert movement in its derivation, and the methodology that will be used in the experiments in this paper. In section 3, we present three real-time sentence processing experiments that test the differing predictions made by the two approaches to *wh*-in-situ using the environment of ACD and intervention effects. We propose a new approach to *wh*-in-situ and show that it makes correct predictions about the processing of multiple *wh*-questions. Section 4 offers a general discussion of the experimental findings and the architecture of the theory that they entail.

2 Theoretical background

In this section we introduce the background for the theory we develop in this paper. Section 2.1 presents the two traditional approaches to *wh*-in-situ, covert movement and in-situ interpretation, and discusses the predictions these theories make regarding the source and extent of covert *wh*- movement in multiple questions. Section 2.2 presents the phenomenon of Antecedent Contained Deletion (ACD), which will be central to our experiments. Section

2.3 presents the methodology that will be used in the experiments, and section 2.4 spells out the predictions made by the two theories for real-time sentence processing.

2.1 Two approaches to interrogative syntax/semantics

The literature on the syntax/semantics of *wh*-questions provides two approaches to the interpretation of in-situ *wh*-phrases: covert movement and in-situ interpretation. Under the covert movement approach, all *wh*-phrases must be structurally adjacent to the head that interprets them in the CP periphery. This approach thus predicts covert movement of in-situ *wh*-phrases as a prerequisite for their interpretation. The in-situ approach invokes a mechanism that interprets *wh*-phrases without any movement. Hence, if covert movement does occur in a given question, it must be triggered by other factors. Below is a brief description of the two approaches.

2.1.1 The covert movement approach

Under the covert movement approach to questions, *wh*-phrases must be adjacent to C in order to be able to make their contribution to the meaning of the question. Consequently, no *wh*-phrase may remain in situ at LF; instead, all *wh*-phrases occur syntactically next to the complementizer, regardless of where they are pronounced (cf. Karttunen 1977; Huang 1982; Nishigauchi 1986; Lasnik and Saito 1992; Hornstein 1995; Hagstrom 1998; Pesetsky 2000; Richards 2001; Cable 2007, 2010).[1,2]

(2) **The covert movement approach to *wh*-in-situ**
Which student [*which professor* [C [Fred introduced ___ to ___]]]

The covert movement approach thus predicts pervasive covert movement in multiple *wh*-questions. Moreover, movement is always triggered for one and the same reason the semantic needs of the *wh*-phrases themselves and it always targets the same syntactic position at LF: C. This approach makes the prediction in (3).

(3) **A prediction of the covert movement approach**
All *wh*-phrases in a question must (overtly or covertly) move to C for interpretation.

[1] Other theories argue that at least in some cases, it is not full *wh*-phrases but rather an operator that moves at LF (Aoun and Li, 1993; Hagstrom, 1998; Pesetsky, 2000; Watanabe, 2001; Kishimoto, 2005, a.o.). Since the target position of movement and the reasons for this movement are the same as in the approach introduced here, we classify these theories here as consistent with the covert movement approach. However, as we will see, even if these theories are classified as in-situ theories, they will be unable to derive the experimental results we present in section 3.

[2] Here and throughout, straight arrows indicate movement and curly arrows to indicate an area in which in-situ composition is used. These curly arrows are used here as a notational convenience only. Dashed arrows indicate covert movement.

2.1.2 The in-situ approach

Under the in-situ approach to questions, no (overt or covert) movement is required in order to assign interrogative meaning to a structure containing *wh*-elements (cf. Hamblin, 1973; É Kiss, 1986; Cheng, 1991; Tsai, 1994; Chomsky, 1995; Reinhart, 1998; Kratzer and Shimoyama, 2002; Shimoyama, 2006). The meaning of a question like (4) can be calculated through a mechanism that passes the meanings of *wh*-words up the structure until they reach C, where they can be interpreted (Rooth 1985, 1992). From this perspective, there is no reason to expect any instances of *wh*-movement that are caused by the semantic needs of the *wh*-words themselves. Even the fact that English questions require overt fronting of one *wh*-phrase is unexpected. To explain this fact, a purely syntactic mechanism must be invoked, unrelated to interrogative semantics, for example an EPP feature requiring C to have a filled specifier (Chomsky, 1981).

(4) **The in-situ approach to *wh*-in-situ**
Which student [C_{+EPP} [Fred introduced ___ to *which professor*]]

The in-situ approach to questions thus makes no predictions about the position of *wh*-phrases at LF. Following standard assumptions in the theoretical literature that the simplest syntactic structure for a sentence is always preferred to a less simple one (cf. Chomsky, 1991, 1993, 1995, 2000; Epstein, 1992; Kitahara, 1997; Fox, 2000; Collins, 2001; Richards, 2001; Reinhart, 2006), it is predicted that *wh*-phrases occupy the position at which they were merged into the syntactic structure. No covert movement occurs for semantic interpretation of *wh*-phrases, (5).

(5) **A prediction of the in-situ approach**
wh-phrases in a question can be interpreted in situ and do not require any movement.

2.2 Antecedent Contained Deletion

In this section we discuss Antecedent Contained Deletion (ACD), which will be central to the experimental methodology introduced in section 2.3 and the experiments presented in section 3.

ACD is a phenomenon found in certain VP ellipsis contexts. For VP-ellipsis to be licensed, a pronounced antecedent VP must exist that is identical to the missing VP.[3] This is straightforward in examples like (6), where the only pronounced VP in the sentence—read a book—can

[3]How to define identity in the domain of ellipsis is a much debated question. For example, experiments have shown that voice mismatches are possible in some contexts but not others (e.g. Kehler, 2001; Arregui et al., 2006; Kertz, 2010; San Pietro et al., 2012, a.o.). It has also been argued that such mismatches are only possible in VP ellipsis but not in sluicing (Merchant, 2013). We will not attempt to contribute to the definition of identity here. We assume that traces count as identical for the purpose of ellipsis parallelism if they bound from parallel positions (e.g. Fox, 2002).

serve as an antecedent for the missing VP. In ACD cases like (7), however, the missing VP appears to be properly contained inside the only possible antecedent VP in the sentence. Matching the missing VP with the antecedent VP should be impossible since the missing VP is properly contained inside its antecedent and so cannot be identical to it.

(6) **VP-ellipsis and its resolution**

a. John read a book and Mary did ⟨missing VP⟩ , too.

b. John read a book and Mary did ~~⟨read a book⟩~~, too.

(7) **ACD and the containment problem**

a. John read every book that Mary did ⟨missing VP⟩ .

b. John read every book that Mary did ⟨??⟩.

To solve the containment problem in (8a), the standard analysis of ACD assumes that the object is covertly moved out of TP_1 to a syntactic position in the higher TP_2, yielding the LF in (8b). The resulting VP, containing only the Verb and the trace of covert movement, can then be used as an antecedent for the missing VP (cf. Williams, 1974, 1977; Sag, 1976; May, 1985; Larson and May, 1990; Johnson, 1996; Heim and Kratzer, 1998; Fox, 2003).

(8) **Resolution of ACD using covert movement**

a. [$_{TP1}$ John read [every book that Mary did ⟨missing VP⟩].

b. [$_{TP2}$ [every book that Mary did ~~read t~~] [$_{TP1}$ John read t]].

ACD can also occur in sentences with a *wh*-phrase complement of the verb. Example (9a) illustrates this for a sentence with an embedded multiple question, where the in-situ *wh*-phrase hosts an ACD site. The containment problem for this sentence is illustrated in (9b-c). To undo containment and allow for ACD resolution, the in-situ *wh*-phrase must undergo covert movement. Once covert movement has occurred, an appropriate antecedent can be found and used for the missing VP, (9d).

(9) **ACD in multiple *wh*-questions and its resolution**

a. John knows [$_{TP1}$ which student
read [which book that Mary also did ⟨missing VP⟩]].

b. John knows [$_{TP1}$ which student read [which book that Mary also did ~~⟨read [which book that Mary also did ⟨missing VP⟩⟩~~]]].

c. John knows [$_{TP1}$ which student read [which book that Mary also did ~~⟨read [which book that Mary also did read [which book that Mary also did ⟨missing VP⟩⟩~~]]]].

d. John knows [$_{TP1}$ which student
[$_{TP2}$ which book that Mary also did ~~⟨read t⟩~~] [read t]]

2.3 Self-paced reading and the Hackl et al. (2012) paradigm

In this section we present the methodology that will be used in the experiments in section 3. The goal of the experiments is to investigate the presence and extent to which in-situ *wh*-phrases undergo covert movement in multiple *wh*-questions. To this end, the experiments will use the paradigm developed in Hackl et al. (2012), which studies the real-time processing of sentences where covert movement has been argued to occur. In particular, this paradigm takes advantage of the inherently linear organization of real-time sentence processing: the human parser integrates material that occurs earlier in a sentence before it encounters material occurring later.

The paradigm relies on two underlying assumptions about the economy of structure building: (a) the linguistic parser always builds the simplest syntactic structure consistent with the linguistic input (cf. Bever, 1970; Frazier and Rayner, 1982; Phillips, 2003), and (b) structures without covert movement are simpler than structures with covert movement (cf. Fox, 1995, 2000; Tunstall, 1998; Frazier, 1999; Anderson, 2004).[4] Given these assumptions, we conclude that the parser does not postulate covert movement in the parse of a sentence until the point at which the parser determines that it is necessary. From that point on, one might expect to find online consequences (detectable as a delay in Reading Times, RTs) of the *reanalysis* of the structure to a less preferred parse.

Hackl et al. (2012) test the covert movement theory of ACD by comparing the processing of sentences that contain non-quantificational objects (*the*, 10a-c) to sentences with quantificational objects (*every*, 10d-f) where this factor is crossed with three different gap sizes inside an attached relative clause: (a) *no ellipsis* using a lexical <u>verb</u>, (b) *small ellipsis* marked by <u>*did*</u>, where the antecedent of the ACD site is the embedded VP headed by *treat*, and (c) *large ellipsis* marked by <u>*was*</u>, where the antecedent of the ACD site is the matrix VP headed by *reluctant*.

(10) **The paradigm in Hackl et al. (2012)**

The doctor was $[_{VP1}$ reluctant to $[_{VP2}$ treat ...

a. **the** patient that the recently hired nurse <u>*admitted*</u> *(no ellipsis)*
b. **the** patient that the recently hired nurse <u>*did*</u> *(small ellipsis)*
c. **the** patient that the recently hired nurse <u>*was*</u> *(large ellipsis)*
d. **every** patient that the recently hired nurse <u>*admitted*</u> *(no ellipsis)*
e. **every** patient that the recently hired nurse <u>*did*</u> *(small ellipsis)*
f. **every** patient that the recently hired nurse <u>*was*</u> *(large ellipsis)*

... after looking over the test results.

ACD resolution involves at least three steps: (i) creating a structure in which antecedent containment is undone; (ii) identifying an appropriate antecedent for the ellipsis; and (iii)

[4] For example, these can be formulated as the Minimal Attachment principle (see e.g. Frazier and Fodor, 1978, and references therein): *Attach each new item into the current phrase marker postulating only as many syntactic phrase nodes as is required by the grammar.*

filling the antecedent into the gap and computation of the resulting meaning. Steps (ii) and (iii) are required for all cases of VP ellipsis. Step (i)—the reanalysis of the structure so as to undo antecedent containment—is only required in the case of ACD. Hackl et al. (2012) generate specific predictions for language processing in real time based on these properties and the assumptions that (a) step (i) of ACD resolution requires covert movement (cf. section 2.2), and (b) that quantificational objects (but not non-quantificational objects) require covert movement for their interpretation, and that this movement targets the lowest position in the structure where the object can be interpreted (cf. Fox, 1995, 2000; May, 1985; Heim and Kratzer, 1998)

In the *definite* conditions in (10a-c), no covert movement is predicted to take place when the definite article is processed. The parser only assumes covert movement after it has been determined that the sentence contains an instance of ACD. This happens after encountering the auxiliaries *did* and *was* in (10b-c), which, together with the immediately following word, signal the presence of an ACD site and thus trigger reanalysis in order to resolve ACD. As discussed above, this reanalysis should incur some processing cost detectable in RTs following the ellipsis site, compared to the baseline with *no ellipsis* (10a). Furthermore, the difference in the locality of covert movement and, concomitantly, the size of the antecedent VP should also be reflected in RTs: the covert movement in (10c) must target a non-local position, above the matrix VP_1 headed by *reluctant*, in order to make the matrix VP available for ACD resolution while the covert movement in (10b) targets a closer position above the embedded VP_2 headed by *treat*. On the assumption that non-local movement and the retrieval of a larger antecedent VP are more costly than local movement and the retrieval of a smaller antecedent VP, (10c) is expected to produce longer RTs than (10b).

For the *quantificational* conditions, different predictions are made. In all of (10d-f), the parser must assume covert movement as soon as it encounters the quantificational object headed by *every*. Furthermore, the movement is expected to be *local* and to target a position just above the embedded VP_2 headed by *treat*. Crucially, this position is high enough to preemptively undo antecedent containment in the case of *small ellipsis* (10e) but not in the case of the *large ellipsis* (10f): the movement triggered by *every* targets the same position that would be independently targeted for the resolution of the *small ellipsis*. Because this movement has already happened earlier in the parse, step (i) of ACD resolution can be avoided, and only steps (ii)-(iii) must apply when the ellipsis marker *did* is encountered. Crucially, this means that at the point of identifying the ACD site no *reanalysis* is predicted for this sentence. Hence, ACD resolution is expected to be easier compared to (10b) since part of the work necessary to resolve ACD has already happened prior to encountering the ACD marker *did* with *every*, but all three steps of ACD resolution must happen when *did* is encountered with *the*.[5]

[5]An anonymous reviewer asks whether this logic would lead us to predict that the reading times of the region at and after the quantifier would be slower than the non-quantificational conditions, because quantifiers should cause a detectable reanalysis effect and therefore a slowdown of reading times when they are encountered. This is possible, but note that no important predictions for our agenda rest on this point. If an effect is found, it may be attributed to surprisal or alternatively to a word-level lexical effect caused by the different in frequency of the quantifier vs. the definite article. On the other hand, if an effect is not

In the case of the *large ellipsis* in (10f), by contrast, the covert movement step that was assumed following the processing of *every* is not sufficient to furnish a suitable antecedent VP: following this local movement, the missing VP is still contained inside its antecedent. Hence, when the auxiliary *was* is reached, the parser must again reanalyze the structure, covertly moving the object a second time, from its position above the embedded VP to a position higher than the matrix VP. This means that no facilitation of ACD resolution is expected in (10f) even though the host DP is quantificational in nature.

Hackl et al. (2012) used sentences in a paradigm as in (10) in a self-paced reading study (Just et al., 1982): participants read sentences that appeared on the screen one word at a time using a moving window display. Residual Reading Times (RRTs) were analyzed for each word in the sentence. Given the methodology and experimental design, the predictions laid out above follow as long as it is the case that readers must encounter the determiner before they reach the gap site. This is compatible with mainstream theories of processing that are currently available in the literature, including for example *serial* models of processing, (e.g. Ford et al., 1982; Frazier and Rayner, 1982; Pritchett, 1992) and *parallel* models of processing, (e.g. MacDonald et al., 1994; Tanenhaus and Trueswell, 1995).

Figure 1 shows RRTs two words after the ellipsis site in Hackl et al.'s experiment. These results indicate that the predictions described above are borne out: When the object is *definite*, ACD resolution is associated with longer RRTs compared to the baseline condition, *no ellipsis* (*Verb*). The increase in RRTs is linear across the three gap size levels (*the-verb* vs. *the-did* vs. *the-was*). When the object is *quantificational*, however, an interaction pattern emerges. No increase is observed between the *every-verb* condition and the *every-did* condition (*small ellipsis*), while a large increase is observed between the *every-did* condition and the *every-was* condition (*large ellipsis*). This is unexpected if the two factors (quantificational vs. non-quantificational object and ACD size) are not linked in some form, but it is the expected result under the assumption that covert movement is required to accommodate both a quantificational object and an ACD site, as the first step in resolving antecedent-contained ellipsis.

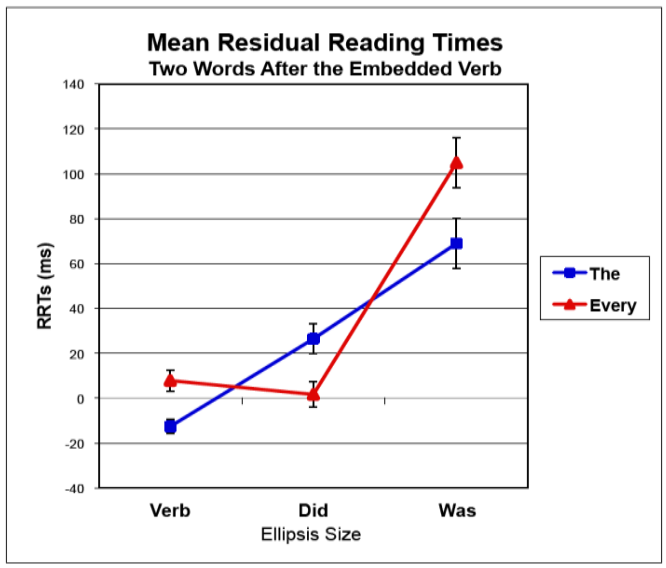

Figure 1: Results of Hackl et al. (2012)

found, we might conclude that the effect was either too small or too fast to detect in this way. Because this is the case, the Hackl et al. paradigm ensures that any effects of the determiner would be resolved in the spillover region between the determiner and the verb site, so that any effects attributed to the ellipsis resolution would not be affected by any earlier word-level effect.

There is a debate in the sentence processing literature about whether or not the size of the antecedent site affects the processing of the ellipsis site (cf. Murphy, 1985; Frazier and Clifton, 2000, 2001; Martin and McElree, 2008, 2009, 2011). We note that the results discussed here do not rely on the answer to this question. Although the current thinking in the literature seems to suggest that a larger antecedent does not necessarily incur a larger cost in the processing of ellipsis, it is possible to attribute the increased processing cost that Hackl et al. (2012) observe for the non-local ACD cases either to the longer covert movement step associated with the *large ellipsis* condition, or to the fact that the *large ellipsis* involves a more complex VP and hence more complex meaning than the *small ellipsis*. Another possible alternative proposed by an anonymous reviewer is that the parser's search for the antecedent is bounded by the structure. That is, regardless of the type of auxiliary, the parser attempts to resolve the ellipsis to the local potential antecedent. Here, the parser first attempts to resolve the ellipsis to the local VP, which is a candidate as long as the object DP that hosts the ACD site has been QRed above that VP. However, in the *large ellipsis* condition, the auxiliaries do not match, and this mismatch triggers a further search which, in turn, involves re-movement of the object DP—involving a second QR step—and re-resolution of the ellipsis site. These additional operations incur a greater processing cost.

2.4 Predictions of *wh*-in-situ theories for the Hackl et al. paradigm

The goal of the present paper is to provide experimental evidence to distinguish between the covert movement approach and the in-situ approach to interrogative syntax/semantics. As we have seen, the two approaches make different predictions regarding the availability of covert movement for in-situ *wh*-phrases in multiple questions, and in particular regarding (a) how much covert movement is predicted to be involved in the derivation of a multiple question, (b) what causes covert movement, and (c) what syntactic position is targeted by covert movement. The predictions of the two approaches are summarized in (11).

(11) **Predictions of the two approaches with regard to covert *wh*-movement**

a. <u>The covert movement approach:</u>
All *wh*-phrases in a question must (overtly or covertly) move to C for interpretation.

b. <u>The in-situ approach:</u>
Wh-phrases in a question can be interpreted in situ and do not require any movement.

Within the Hackl et al. (2012) paradigm, the covert movement approach and the in-situ approach to the interpretation of in-situ *wh*-phrases make different predictions with regard to facilitation of ACD resolution in sentences in which an ACD gap site is hosted inside a *wh*-phrase, e.g. (12a-b):

(12) **ACD hosted by *wh*-phrase in the Hackl et al. paradigm**

The conductor asked *which soloist* was $[_{VP1}$ willing to $[_{VP2}$ perform...

a. **which** concerto that the brilliant protege did ... *(small ellipsis)*

b. **which** concerto that the brilliant protege *was* ... *(large ellipsis)*

...and restructured the rehearsal accordingly.

In the covert movement approach, all *wh*-phrases must move *non-locally* to C for interpretation. As a result, we predict that both *small* and *large* ellipsis should be relatively easy to process, because antecedent containment will have been undone by covert *wh*-movement before the parser reaches the gap site. When the parser encounters the gap site, all it needs to do is find an antecedent for the missing VP and nothing more.

In the in-situ approach, *wh*-phrases can be interpreted *in-situ* and hence the parser will not move the in-situ *wh*-phrase to C when it is encountered. Upon reaching the ellipsis site, the parser must reanalyze the structure and covertly move the *wh*-object to a position above the missing VP, in order to construct an appropriate antecedent for the ellipsis. Hence, a high processing cost should be associated with the resolution of the ACD site in both the *small ellipsis* condition and in the *large ellipsis* condition. The predictions of the two approaches are summarized in (13), and will be tested in Experiment 1 below.

(13) **Predictions of the two approaches with regard to ACD resolution**

a. The covert movement approach:
The resolution of both small and large ellipsis is facilitated.

b. The in-situ approach:
The resolution of both small and large ellipsis is not facilitated.

3 Distinguishing between the approaches to *wh*-in-situ: Experimental evidence

In the following sections we present the results of three experiments that test the predictions of the covert movement approach and the in-situ approach to *wh*-in-situ. All three experiments use the paradigm in Hackl et al. (2012) as a tool for detecting covert movement in multiple *wh*- questions.

Previous processing work, as well as rating and corpus studies, show that questions with D-linked *wh*-phrases (Pesetsky, 1987) are easier to process than questions with bare *wh*-pronouns (Arnon et al., To appear; Clifton et al., 2006; Fanselow et al., 2008; Featherston, 2005a,b; Frazier and Clifton, 2002; Hofmeister et al., 2007), and furthermore that *superiority-obeying* questions are easier to process than *superiority-violating* questions. In order to make the experimental items as easy to process as possible, the items in Experiments 1-3 all use D-linked *wh*-phrases in a superiority-obeying word-order.

3.1 Experiment 1: *every* vs. *which*

This experiment tests the core predictions of the covert movement approach and in-situ approach to in-situ *wh*-phrases. In particular, we compare the behavior of questions with an ACD gap hosted by a *wh*-phrase with the behavior of questions with an ACD gap hosted by the quantificational determiner *every*.

3.1.1 Design and materials

Experiment 1 presented participants with (embedded) *wh*-questions headed by a subject *wh*-phrase. Two factors were crossed: (a) *determiner*: whether the embedded question contained the quantificational determiner *every*, yielding a simplex *wh*-question, or a second *wh*-phrase, yielding a multiple *wh*-question; and (b) *ellipsis size*: whether the sentence contained a *small ellipsis* marked by <u>*did*</u>, where the antecedent of the ACD site is the embedded VP, VP_2, or *large ellipsis* marked by <u>*was*</u>, where the antecedent of the ACD site is the matrix VP, VP_1. A sample item is given in (14) below:[6]

(14) **Sample target item in Experiment 1**

The conductor asked *which soloist* was $[_{VP1}$ willing to $[_{VP2}$ perform...

a. **every** concerto that the brilliant protege <u>*did*</u> ... *(small ellipsis)*
b. **which** concerto that the brilliant protege <u>*did*</u> ... *(small ellipsis)*
c. **every** concerto that the brilliant protege <u>*was*</u> ... *(large ellipsis)*
d. **which** concerto that the brilliant protege <u>*was*</u> ... *(large ellipsis)*

...and restructured the rehearsal accordingly.

There were 28 sentence templates following the sample paradigm in (14). Each sentence in a template employed either *every* or *which* as the determiner of the object DP. This DP hosted a relative clause with an ACD site marked with an auxiliary verb. The auxiliary <u>*did*</u> marked a *small ellipsis* corresponding to the embedded predicate, VP_2, and the auxiliary <u>*was*</u> marked a *large ellipsis* corresponding to the matrix predicate, VP_1. After the ellipsis site, the sentences had continuations beginning with a clausal conjunction or disjunction, which varied in length but were at least 5 words long, providing a spillover region for detecting possible processing difficulties associated with ACD resolution. See the Appendix for a full list of the materials.

Because the experiments were conducted online, it was not possible to control the participants screen size. Consequently, in order to ensure that the region of interest was read without interruptions that may artificially affect the data, all the sentences were presented on two lines, with the line break in target sentences always placed immediately following the verbal complex (that is, the first line of the sentence was the first line in (14), and the

[6]To simplify the discussion, in what follows we ignore the highest predicate embedding the question. We thus refer to the lower VP inside the embedded question as the embedded VP and to the larger VP inside the embedded question as the matrix VP.

second line contained the text in lines a-d and the continuation following these lines).[7] Target items were counterbalanced across four lists using a Latin Square design and combined with 48 filler sentences of various types resulting in a total of 76 sentences. Non-target items included sentences that were similar to the target items in structure, in length and in containing quantifiers. 18 filler sentences resembled the target sentences in all aspects but contained a lexical verb instead of ellipsis (*did*, *was*). Filler sentences additionally contained line breaks in different positions, making it impossible for participants to anticipate where a line break might occur, or whether or not there will be ellipsis in the sentence. The remaining filler sentences were taken from an unrelated study.

Each experimental item was followed by a yes/no comprehension question. The questions asked about different aspects of the sentences, including about material inside the relative clause and about the predicates used in the sentences, to ensure that participants were processing all parts of the sentence at a deep level. The correct answers to half of the questions was *yes* and to the other half *no*.

3.1.2 Methods

Experiment 1 used the moving window self-paced reading methodology and was hosted on Ibex Farm.[8] Participants were presented with sentences that appeared on the screen one word at a time in a moving window display. Each trial begins with a series of dashes marking the length of the sentence. Participants press the spacebar to reveal the next word of the sentence. Each press of the spacebar reveals a new word while the previous word is again replaced with dashes. The amount of time a participant spends reading each word is recorded (RT). After the final word of each sentence, a yes/no comprehension question appears, asking about information contained in the sentence. Participants responded by pressing 1 for Yes or 2 for No. No feedback was given about whether the answer to the question was correct or incorrect.

Before beginning the experiment, participants were given detailed instructions about the experiment and then read and accepted a consent statement. Participants were instructed to read the sentences at a natural rate to ensure understanding. They were also instructed to answer the comprehension questions as accurately as possible. There were three practice items before the experiment began. Each experiment took approximately 30 minutes to complete.

Subjects for the experiments were recruited through Amazon Mechanical Turk and they were paid $1.5 for their participation. The participants were asked about their native language but were told that payment was not contingent on their response. To further ensure that only native speakers of English participated in the experiments, IP addresses of participants

[7]Testing on a number of standard monitors showed this method to consistently avoid line breaks inside the region of interest, and was furthermore found to be the most natural among several other options in a pilot study.

[8]Ibex: Internet Based Experiments, created and maintained by Alex Drummond, accessible at http://spellout.net/ibexfarm/.

were restricted to the US using Amazon Mechanical Turks user interface. Participation was further restricted so that only Turk Workers with a overall approval rate of over 95% of all their submissions were allowed to participate in the experiments.

3.1.3 Predictions

The *every* conditions are expected to replicate the results of Hackl et al. (2012). That is, we expect to find a main effect of ellipsis size, such that *small ellipsis* is easier to process than *large ellipsis*: since *every* triggers covert movement to a position above the embedded VP_2 (headed by *perform* in (14)) as soon as the quantifier is encountered, we expect antecedent containment to be preemptively undone in the case of the *small ellipsis* (marked with *did*) (14a), leading to facilitation of ACD resolution in this case. However, since this movement does not target a position high enough to undo antecedent containment in the case of the *large ellipsis* (marked with *was*) (14c), we expect ACD resolution to be relatively more difficult in this case: once the auxiliary *was* is reached, the parser must perform a second reanalysis, covertly moving *every* from its QRed position above the embedded VP_2 to a position above the higher VP_1 (headed by *willing* in (14)), in order to allow for ACD resolution. These two conditions thus provide us with a baseline contrast against which to compare the *which* conditions in (14b,d).

For the which conditions, the two approaches to in-situ *wh*-phrases make different predictions:

In the covert movement approach, all *wh*-phrases must move *non-locally* to C for interpretation. Both *small* and *large* ellipsis are predicted to be relatively easy to process because antecedent containment is undone by covert *wh*-movement before the parser reaches the ellipsis site. When the parser encounters the ellipsis siteregardless of whether the ellipsis is *small* or *large*all that is left to do is find an antecedent for the missing VP. We thus expect an interaction, such that the *which-did* and *which-was* conditions both pattern with the *every-did* condition and exhibit facilitation effects, compared to the remaining *every-was* condition where we predict participants to exhibit increased difficulties with ACD resolution.

According to the second approach, the in-situ *wh*-phrase can be interpreted in-situ. Hence, encountering the in-situ *wh*-phrase will not trigger reanalysis that could facilitate downstream ACD resolution. Only upon reaching the ellipsis site itself will the need for reanalysis be apparent. Thus processing costs for ACD resolution are predicted to reflect both covert movement of the *wh*-object to a position above the missing VP as well as the retrieval of the appropriate antecedent for the elided VP and so should be relatively higher for both the *small* and *large* ellipsis conditions. Under this approach we thus expect to find a main effect of the object type, such that sentences with a relative clause headed by *which* are more difficult to process than sentences with a relative clause headed by *every*. This main effect may be accompanied by an interaction, such that the two which conditions pattern with *every-was* and are more difficult to process than *every-did*, or they may be even more difficult than the *every-was* condition.

(15) **Predictions with regard to ACD resolution in Experiment 1**

a. The covert movement approach:
The resolution of both *small* and *large* ellipsis is facilitated.
Which-did and *which-was* pattern with *every-did* and are easier to process than *every-was*.

b. The in-situ approach:
The resolution of both *small* and *large* ellipsis is not facilitated.
Which-did and *which-was* are more difficult to process than *every-did*; they are at least as difficult to process as *every-was*.

3.1.4 Results

61 native speakers of English participated in this study. The following exclusion criteria were used to filter the results of this experiment and all subsequent ones: participants who held the spacebar continuously pressed instead of reading the sentences one word at a time as instructed, participants who participated in the study more than once, participants who submitted the entire survey in less than 10 minutes,[9] participants with an average reaction time of over 700ms,[10] and participants with low accuracy rates in response to comprehension questions (<75% on filler trials and <75% on target trials) were excluded from the study. Twenty participants in Experiment 1 were excluded from the analysis for these reasons.[11] In addition, two target sentences and no filler sentences were excluded from the analysis because of low accuracy (<60% across participants).

Questions across the full experiment (targets and fillers) were answered correctly 87.5% of the time across participants; questions for experimental items were answered correctly on 83.3% of trials. The data was trimmed as follows: RTs from the first and last words of all items, RTs faster than 90ms or slower than 2000ms, and any RTs that were more than 2 standard deviations faster or slower than the average RTs for each subject (calculated per condition) were excluded from the analysis. Overall, less than 1% of the data were lost due to these criteria.[12] Figure 2 shows the mean residual reading times (RRTs)[13] for the two regions of interest for the four target conditions.

A linear mixed effects model was fit to the data using *R* and the *R* package *lme*4 (Bates and Sarkar, 2007). The model predicted RRTs from the two factors of interest: *determiner* (*every* vs. *which*) and *ellipsis size* (*small ellipsis* marked by did, vs. *large ellipsis* marked by

[9] Average completion time for all of the experiments we present here was at least 25 minutes.

[10] Particularly slow reading times in our experiments tended to reflect long breaks and distracted behavior of the participants, introducing extraneous noise into the results. Particularly fast reading times were similarly contributed by distracted participants.

[11] Although this is exclusion rate is quite high, we believe that it is necessary in order to filter the relatively higher noise level in Amazon Mechanical Turk participants as compared to lab participants. We believe that this more parsimonious criterion helps ensure the validity of the results we report here.

[12] Here and in the other experiments, the results remain statistically unaltered if this step is not performed.

[13] RRTs were calculated based on a regression equation predicting reading time from word length using all words from all experimental items, except for the first word and the last word of the sentence.

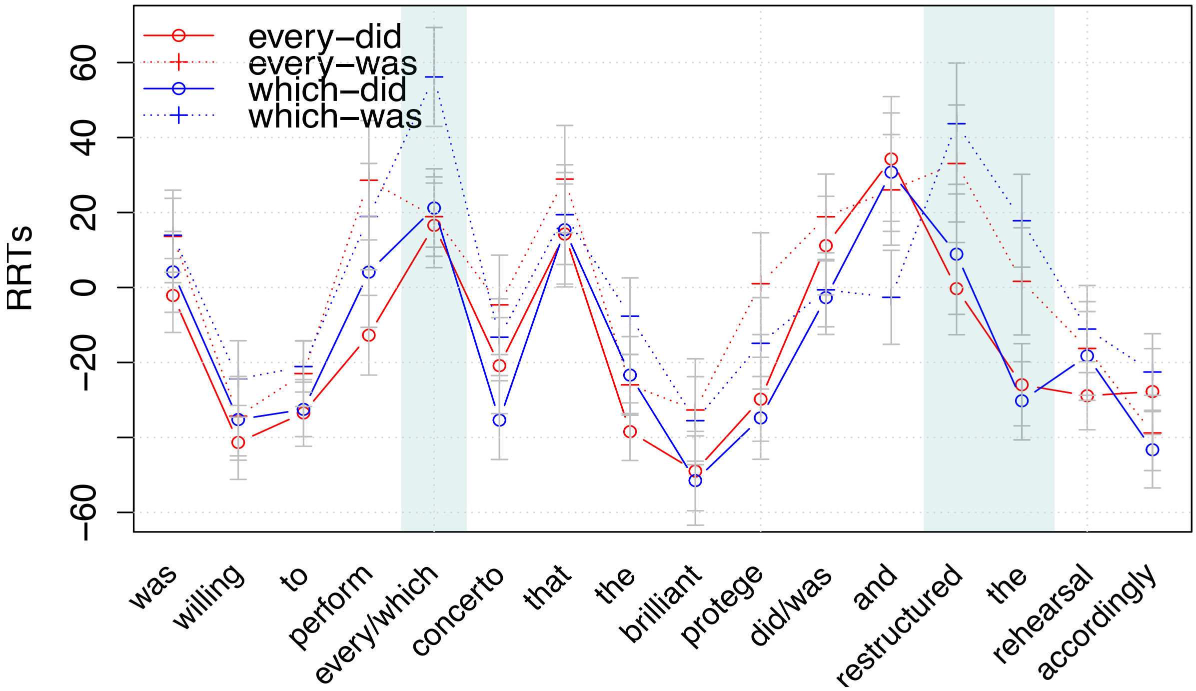

Figure 2: Residual reading times in target items in Experiment 1

was).[14] The model contained random intercepts and slopes for both predictors for subjects and items (Baayen, 2004; Barr et al., 2013).

The results show a main effect of *determiner* at the slot at which the determiner appeared in the sentence (log likelihood tests comparing a model with and without the effect of *determiner*, p<0.05). This result is driven by the fact that reaction times in the *which* condition were slower than the reaction times in the *every* condition, across both ellipsis conditions.[15] The results additionally show a main effect of *ellipsis size* two words and three words after the auxiliary site (log likelihood tests, ps<0.05).[16] This result is driven by the fact that the

[14]Similar results are obtained for logRTs in our data. We report the results for RRTs for convenience.

[15]Note, in particular, that the *which-was* condition appears to be slower than the other three conditions. However, the *determiner*×*ellipsis size* interaction is not significant (p=0.344).

[16]Note that the earliest we might expect an effect is on the word following the auxiliary verb (*did*/*was*) and not on the auxiliary itself. At this point in the sentence, readers encounter a conjunction or disjunction that can only be attached at the clausal level, indicating that the previous clause contained ellipsis. We observe the effect in the spillover region, one and two words downstream. This is common in self-paced reading experiments, in experiments involving the Hackl et al. paradigm, e.g. Breakstone et al. (2011), and in many other studies (e.g. Clifton et al., 1999; Wagers and Phillips, 2009; Kazanina and Phillips, 2000; Xiang et al., 2011; Polinsky et al., 2012; Polinsky and Potsdam, Forthcoming, among others). Throughout this paper, all the experiment we will see exhibit the effect in this same region. It is important to note that the logic of this paradigm makes no predictions about where exactly an effect should be observed, as long as the effect happens inside the spillover region. This is an inherent weakness of the self-paced reading methodology, but it is not constrained to our experiments alone. To interpret our effects in the way that we do, they must happen only after the parser could have determined the presence of ACD, and they must happen within a region that is uniform across all conditions so that nothing else in that region could have

resolution of *small ellipsis* is faster than the resolution of *large ellipsis* for both *every* and *which*. There were no differences between the two determiners at these slots, and there were no other significant effects in the results. The results of the model for the third word after the auxiliary site are summarized in Table 1.

Predictor	Coefficient	Standard Error	t value
Intercept	-31.591	18.851	-1.676
Determiner	3.586	16.018	0.224
Ellipsis size	39.8416	15.651	2.546
Determiner×*Ellipsis size*	2.665	20.628	0.129

Table 1: Results of Experiment 1

3.1.5 Discussion

We find two effects in Experiment 1. First, the main effect of *determiner* in the first region of interest may be attributed to the relatively higher complexity of a multiple question compared to that of a simplex question. When the parser encounters the in-situ *wh*-phrase in the *which* conditions, it realizes that the sentence will be paired with a more complex semantics than in the case of the simplex question with *every*. Regardless of the cause of this effect, it shows that our participants were processing the sentences at least at a depth sufficient for detecting the difference in determiner.

Second, we find a main effect of *ellipsis size* in the second region of interest, following the auxiliary verb, such that sentences with a *small ellipsis* are read faster than sentences with a *large ellipsis*. This is the case for both determiners: *every* and *which*. To see this more clearly, observe Figure 3, which compares reading times for *every* and *which* two words after the auxiliary verb. As we can see, the *ellipsis size* manipulation affects the two determiners equally.

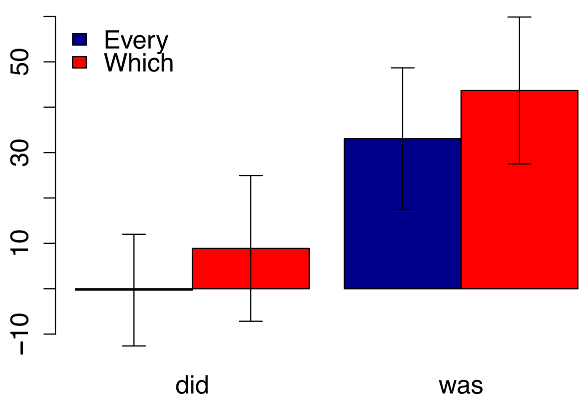

Figure 3: RRTs for 2$^{\text{nd}}$ word after AUX

This result is not predicted by either traditional approach to *wh*-in-situ. Recall that the covert movement approach predicts facilitation of both *small* and *large* ellipsis, because the in-situ *wh*-phrase must move to C for interpretation, preemptively undoing antecedent containment in both ellipsis conditions. We would thus expect that RTs for both *which* conditions, irrespective of whether they involve local or non-local ACD, would be lower than those for the *every* conditions. The in-situ approach, on the other hand, assumes that the *wh*-phrase can be interpreted without any movement at all, and hence predicts no facilitation by

generated the effects. Our materials are constructed to ensure this.

an upstream *which* for either the *small* or *large* ellipsis conditions. However, the results of Experiment 1 show an effect of ellipsis size but no effect of *determiner*, which is not explained under both approaches to *wh*-in-situ.

Based on the results of Hackl et al. (2012), we may take the fact that there is no difference between *every-did* and *which-did* to indicate that local ACD resolution is facilitated in both cases. More specifically, if *which* where a determiner that could be interpreted in situ like the we should have seen relatively longer RTs for *which-did*, just like Hackl et al. (2012) did for *every-did*. The fact that we didnt shows that *wh*-phrases behave like traditional quantificational determiners such as *every* with regard to ACD resolution in real time.

This is compatible with a view under which *wh*-phrases, too, are quantifiers that must covertly move (via QR) to the nearest propositional node for interpretation.[17] Similar proposals have been previously made by several researchers for a variety of languages (cf. Baker 1970; Dornisch 2000 for Polish, Huang 1995; Kim 1991 for Korean, Rullmann and Beck 1998). We propose that once the *wh*-phrase has been integrated into the structure, it does not require any further movement: it may be interpreted in-situ at the first position in which it can be interpreted in the structure. This proposal can be viewed as a modified version of the in-situ approach: the movement of *wh*- phrases is always forced by external considerations such as the interpretability of the *wh*-phrase, but it is not the case that the *wh* can always be interpreted in the position where it occurs in the overt syntax: some movement step is required whenever a *wh*-phrase occurs in object position. We propose that the movement step assumed by the parser is the smallest that can produce an interpretable structure. The approach we propose is summarized in (16)-(17):

(16) **The status of *wh*-phrases**
wh-phrases are existential quantifiers.

(17) **The *partial movement* approach**
A *wh*-phrase must be interpreted at a position with propositional type at LF.

To substantiate this approach and its predictions, below we present Experiments 2-3. Experiment 3 will test a prediction of the *partial movement* approach that if the partial movement step is forced to be long-distance via external interpretability considerations, we expect to detect an increased domain in which ACD resolution is facilitated. As we will see, this prediction is borne out. We will return to a detailed discussion of this prediction in section 3.3, but first we present Experiment 2, whose aim is to deal with an alternative interpretation of the results of Experiment 1. One possible alternative explanation for the results of Experiment 1 is that the experimental manipulation did not in fact succeed as intended. In particular, we must entertain and reject the possibility that participants failed to process the sentences at a deep level, and that instead of seeing any facilitation effects in our sentences we are only seeing a *complexity of antecedent effect*.

[17]See Heim and Kratzer (1998) for a discussion of the type-mismatch problem with quantifiers in object position.

Long distance dependencies, such as those required for the resolution of ellipsis, are constructed by integrating temporally and structurally distant linguistic material. As such, they require the support of working memory resources for their completion (Foraker and McElree, 2011). In order to establish a dependency, the parser must retrieve previously processed material from working memory at the gap position, and find an appropriate antecedent for the ellipsis. The distance between the gap site and the antecedent affects the retrieval process, resulting in longer reading times and decreased acceptability for longer dependencies (cf. Gibson, 1998; van Dyke and Lewis, 2003; Lewis et al., 2006; Warren and Gibson, 2002). Relatedly, we might expect semantically more complex antecedents (e.g. *willing to perform*) to be harder to retrieve from memory than simpler antecedents (e.g. *perform*).

One possible interpretation of Experiment 1, then, is that the Hackl et al. (2012) paradigm was not successfully replicated. Instead, participants were not reading the sentences carefully and were not affected by the *determiner* manipulation at all. A similar concern is that the experimental paradigm is not sensitive enough to detect differences between the processing of different quantifiers, perhaps because an embedding inside a question presents too much of a challenge to the participants. Hence, Experiment 1 only exhibits an effect of complexity of the antecedent, where the processing of long-distance ellipsis with a more complex antecedent is more costly than that of short-distance ellipsis with a simpler antecedent, and nothing more. To address this concern, first note that some comprehension questions directly targeted the relative clause, to ensure that it was processed at a deep level. Those questions did not suffer from lower accuracy rates than other comprehension questions. We furthermore detect a main effect of *determiner* once *which* and *every* are read, ensuring that participants did indeed pay attention to the determiners in the sentences.

However, to more directly address the concern that the Hackl et al. (2012) paradigm might not have worked as expected, Experiment 2a-b will attempt to replicate the Hackl et al. (2012) results—comparing the behavior of *every* and *the*—in the context of an embedded question, and then additionally compare the behavior of *which* and *the* in the same context. As we will see below, we find that ACD resolution with the quantificational determiner *every* is facilitated compared to ACD resolution in sentences with the non-quantificational definite article *the*, as predicted by the results of Hackl et al. (2012). We furthermore find that ACD resolution in sentences with *which* is facilitated compared to ACD resolution in sentences with the definite article *the*. This result will eliminate the concern that the results of Experiment 1 do not show any facilitation effects with *which*.

3.2 Experiment 2a-b: *the* vs. *every* and *the* vs. *which*

The goal of Experiment 2 is to ensure that the paradigm used in Experiment 1 is in principle sensitive enough to detect differences in the behavior of different determiners. Experiment 2a will attempt to replicate the Hackl et al. (2012) paradigm in a context similar to that of Experiment 1, using an embedded question instead of a simple declarative sentence. Experiment 2b will then compare the behavior of multiple questions with *which* with the behavior of sentences with the non-quantificational definite article *the*. To allow for a direct comparison with Experiment 1, Experiment 2 uses the same materials as in Experiment 1, with minor changes to accommodate the experimental manipulation of this experiment.

3.2.1 Design

Like Experiment 1, Experiment 2 presented participants with (embedded) *wh*-questions headed by a subject *wh*-phrase. Two factors were crossed: (a) *determiner*: whether the embedded question contained the quantificational determiner *every*, the *wh*-word *which*, or the definite article; and (b) *ellipsis size*: whether the sentence contained a *small ellipsis* marked by *did*, where the antecedent of the ACD site is the embedded VP_2, or *large ellipsis* marked by *was*, where the antecedent of the ACD site is the matrix VP_1. *Determiner* was treated as a between-subject factor: Experiment 2a compares *every* and *the*, and Experiment 2b compares *which* and *the*. The missing comparison, *which* and *every*, has already been done in Experiment 1. Sample items are given in (18)-(19):

(18) **Sample target item in Experiment 2a**

The conductor asked *which soloist* was [$_{VP1}$ willing to [$_{VP2}$ perform...

a. **every** concerto that the brilliant protege *did* ... *(small ellipsis)*
b. **the** concerto that the brilliant protege *did* ... *(small ellipsis)*
c. **every** concerto that the brilliant protege *was* ... *(large ellipsis)*
d. **the** concerto that the brilliant protege *was* ... *(large ellipsis)*

...and restructured the rehearsal accordingly.

(19) **Sample target item in Experiment 2b**

The conductor asked *which soloist* was [$_{VP1}$ willing to [$_{VP2}$ perform...

a. **which** concerto that the brilliant protege *did* ... *(small ellipsis)*
b. **the** concerto that the brilliant protege *did* ... *(small ellipsis)*
c. **which** concerto that the brilliant protege *was* ... *(large ellipsis)*
d. **the** concerto that the brilliant protege *was* ... *(large ellipsis)*

...and restructured the rehearsal accordingly.

The same 28 target sentences from Experiment 1 were used, along with the same 48 filler items. The only change introduced to the sentences was to the determiners, as indicated above. The comprehension questions to some items were also minimally changed to accommodate this manipulation. Experiment 2 used the same methods as described above for Experiment 1. See the Appendix for a full list of the materials.

3.2.2 Predictions

We expect Experiment 2a to replicate the results of Hackl et al. (2012). In particular, we expect to see an effect of *ellipsis size*, such that *small* ellipsis is easier to process than *large* ellipsis for both *the* and *every*. In addition, we expect to find a difference in the processing of ACD in sentences with a relative clause headed by *every* and sentences with a relative clause headed by *the*, such that the processing of ACD in sentences with *every* is facilitated compared to sentences with the.

In the *every* conditions (18a,c), the parser must assume covert movement as soon as it encounters *every*. This movement is expected to be local and to target a position above the embedded VP_2 headed by *perform* in (18), a position that is high enough to preemptively undo antecedent containment in the case of *small* ellipsis (18a) but not in the case of the *large* ellipsis (18c). Hence, the processing costs at the ellipsis site in the *small ellipsis* condition (19a) should be lessened since part of the work to resolve ACD, specifically reanalysis to undo antecedent containment, has already happened prior to encountering the ACD site. When the parser encounters *did* all it needs to do is find an antecedent for the missing VP and nothing more. In the case of the *large* ellipsis in (18c), the covert movement that was assumed following the processing of *every* is not sufficient: after local movement of the object DP the missing VP is still contained inside its antecedent. Hence, when the auxiliary *was* is reached, the parser must again reanalyze the structure, covertly moving the object a second time, from its position above the embedded VP_2 to a position higher than the matrix VP_1. Hence, a high processing cost should be associated with the resolution of the *large ellipsis* in (18c).

In the *definite* conditions in (18b,d), no covert movement is predicted to take place when the definite article is encountered. The parser only assumes a structure with covert movement of the object when it encounters the auxiliaries *did* and *was*, as the ACD marker is the earliest point at which the need for moving the object DP is detectable. The fact that processing the ACD site requires both reanalysis and retrieval of an antecedent is expected to result in relatively high processing costs following the ellipsis site. Moreover, just like in the case of *every*, we expect that the processing costs for the *large ellipsis* condition should be higher than those associated with the *small ellipsis*, since retrieving a more complex antecedent VP is more difficult and requires longer distance covert movement than in the case of the small ellipsis.

We furthermore expect to find the same behavior pattern with which in Experiment 2b, (19): if *which*, like *every*, is a quantifier in object position that must QR to the first propositional node in the structure for interpretation, we expect to find that *which*, like *every*, facilitates the resolution of small ellipsis with *did*, but not of large ellipsis with *was*, for the same reasons as described above for *every*. We expect the not to facilitate ACD resolution of any size, and hence we predict that sentences with the to be relatively more difficult to process than sentences with *which*.

3.2.3 Results

165 native speakers of English participated in this study: 84 subjects participated in Experiment 2a and 81 participated in Experiment 2b. 21 subjects were excluded from the analysis of Experiment 2a and 24 subjects were excluded from the analysis of Experiment 2b using

the same exclusion criteria specified in Experiment 1. Three target sentences and one filler sentence were excluded from the analysis of Experiment 2a and three target sentences and two filler sentence were excluded from the analysis of Experiment 2b because of low accuracy (<60% across all participants).

Questions across the full experiment (targets and fillers) were answered correctly 86.7% of the time across participants in Experiment 2a and 85.8% of the time in Experiment 2b; questions for target items were answered correctly on 84.7% of trials in Experiment 2a and 83.8% of the time in Experiment 2b. The data was trimmed using the same criteria described for Experiment 1. Overall, less than 1% of the data was excluded from the analysis. Figure 4 shows the mean residual reading times for the region of interest for the four target conditions in Experiment 2a, comparing the processing of sentences with *the* and *every*.

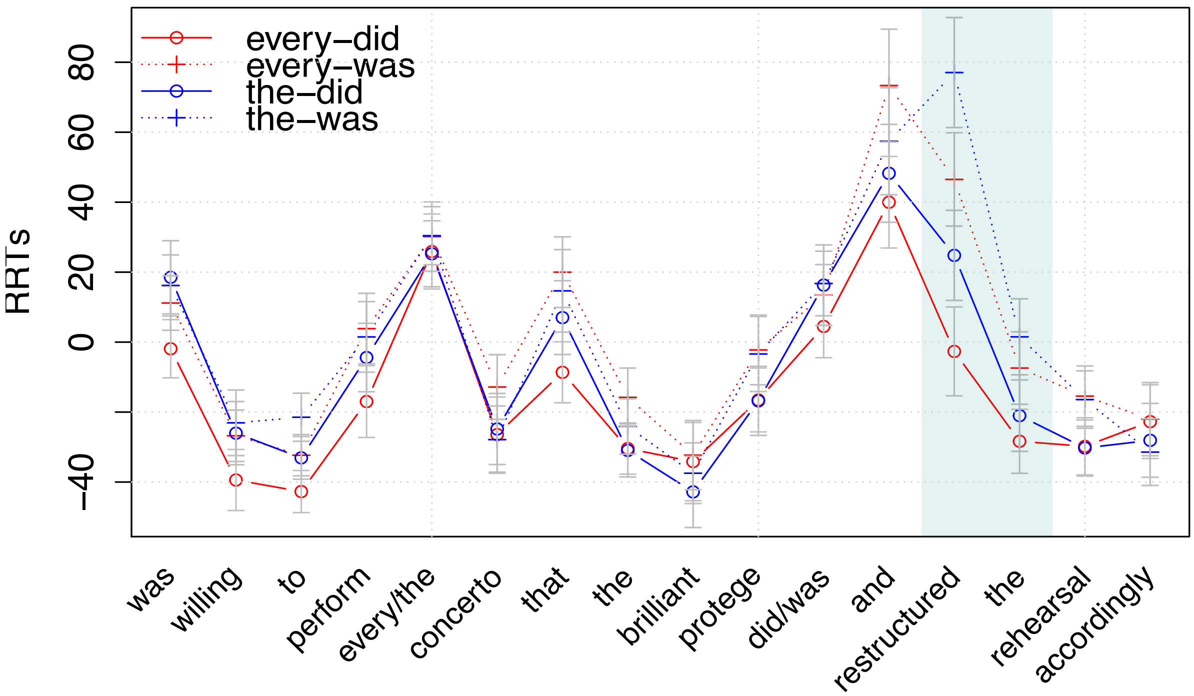

Figure 4: Residual reading times in target items in Experiment 2a

A linear mixed effects model with random intercepts and slopes for *ellipsis size* for subjects and items was fit to the data.[18] The model predicted RRTs from the two factors of interest: *determiner* (*every* vs. *the*) and *ellipsis size* (*small ellipsis* marked by *did*, vs. *large ellipsis* marked by *was*). The results show a main effect of *ellipsis size* two and three words after the auxiliary verb site and a main effect of *determiner* two words after the auxiliary verb site (log likelihood tests comparing a model with and without the predictor of interest, ps<0.05). These results are driven by the fact that the resolution of *small ellipsis* is faster than the resolution of *large ellipsis* for both every and the, and furthermore that the resolution of ACD in sentences with a relative clause headed by *every* is faster than the resolution of

[18]A more specified model that includes the effect of *determiner* yields a false convergence.

ACD in sentences with a relative clause headed by *the*. There were no other significant effects in the data. The results of the model for the second word after the auxiliary site are summarized in Table 2.

Predictor	Coefficient	Standard Error	t value
Intercept	3.304	20.959	0.158
Determiner	21.780	16.517	1.319
Ellipsis size	39.008	19.510	1.999
Determiner×*Ellipsis size*	12.207	23.441	0.521

Table 2: Results of Experiment 2a

Next, we examine the results of Experiment 2b, comparing the determiners *the* and *which*. Figure 5 shows the mean RRTs for the region of interest for the four target conditions.

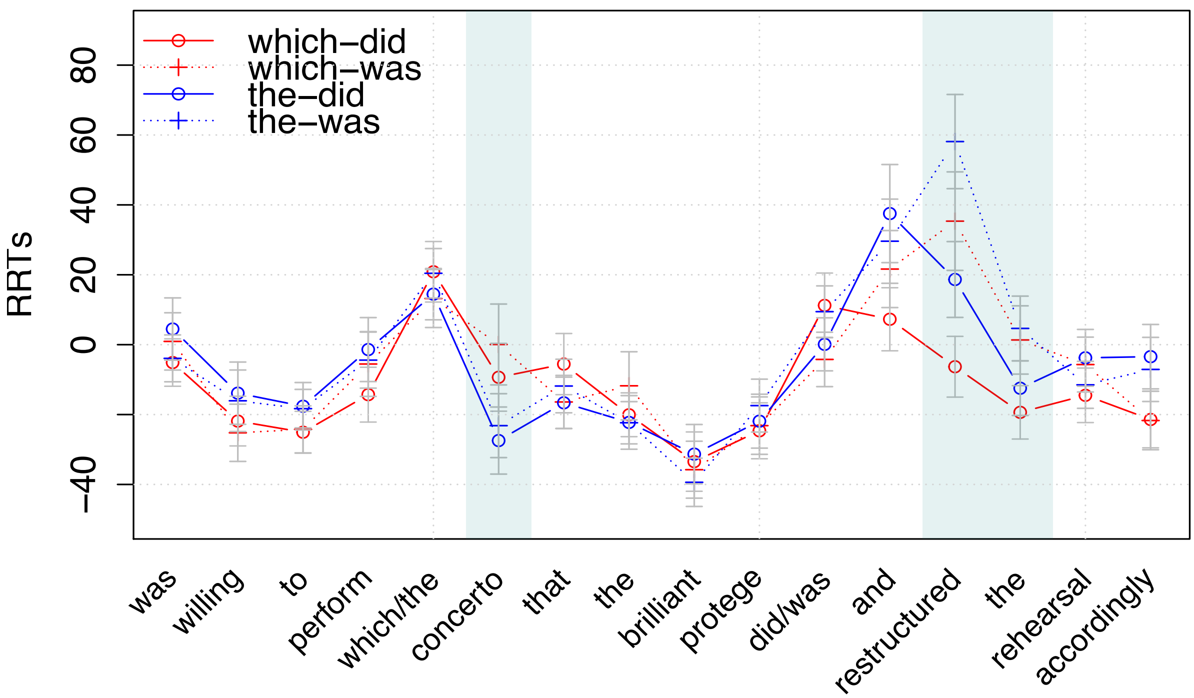

Figure 5: Residual reading times in target items in Experiment 2b

A linear mixed effects model with random intercepts and slopes for *ellipsis size* for subjects and items was fit to the data. The model predicted RRTs from the two factors of interest: textitdeterminer (*which* vs. *the*) and *ellipsis size* (*small ellipsis* marked by *did*, vs. *large ellipsis* marked by *was*). The results show a main effect of *ellipsis size* two and three words after the auxiliary verb site and a main effect of *determiner* two words after the auxiliary verb site (log likelihood tests comparing a model with and without the predictor of interest, ps<0.05). These results are driven by the fact that the resolution of *small ellipsis* is faster than the resolution of *large ellipsis* for both *which* and *the*, and furthermore that the resolution of ACD in sentences with a relative clause headed by *which* is faster than the resolution of ACD in sentences with a relative clause headed by *the*. There were no other significant effects in the data. The results of the model for the second word after the auxiliary site are summarized in Table 3.

Predictor	Coefficient	Standard Error	t value
Intercept	16.572	15.716	1.054
Determiner	-22.748	14.213	-1.600
Ellipsis size	42.714	15.949	2.678
Determiner×*Ellipsis size*	-5.117	20.483	-0.250

Table 3: Results of Experiment 2b

3.2.4 Discussion

The results of Experiment 2a-b confirm that the Hackl et al. (2012) paradigm extends to the context of an embedded question. In particular, we find—in addition to the main effect of *ellipsis size* also a main effect of *determiner*, such that sentences with *every* are processed faster than sentences with *the*, and sentences with *which* are also processed faster than sentences with *the*. That is, *every* and *which* pattern together and facilitate ACD resolution more than parallel sentences with the. To see this more clearly, consider Figure 6, which compares the reading times of *the*, *every* and *which* two words after the auxiliary verb site in Experiments 2a-b.

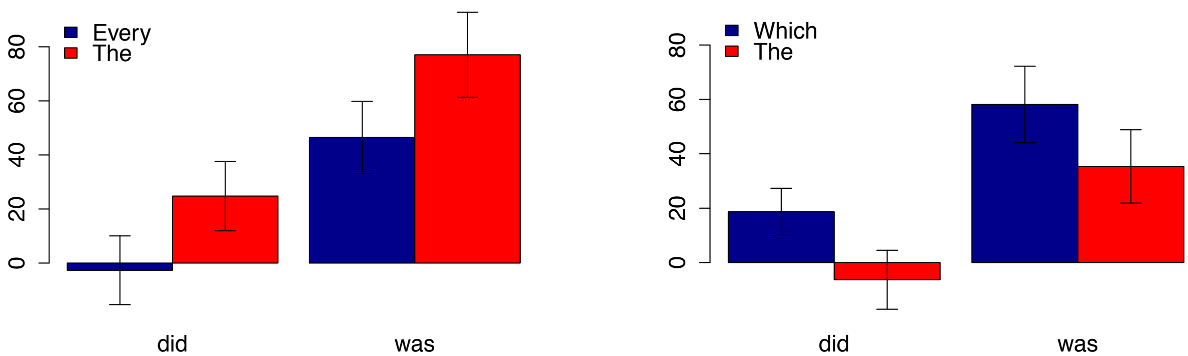

Figure 6: RRTs two words after AUX in Experiments 2a (left) and 2b (right)

For the results of Experiment 2a, we adopt Hackl et al.'s (2012) explanation and assume that this is so because the parser must assume covert movement with *every* as soon as the quantifier is encountered, but no such covert movement is assumed with *the*.[19] As a result,

[19]However, an important difference between our results and Hackl et al.'s (2012) results is that while Experiment 2 yields two main effects, Hackl et al. observed an interaction, such that *every-was* and *the-was* were not significantly different from each other. This played an important role in Hackl et al.s argument that only local QR facilitates ACD resolution, which we are unable to replicate here. However, the results

covert movement must always be assumed to take place at the point of ACD resolution in the case of *the* but not in the case of *every*: when a *small ellipsis* (marked with *did*) is encountered, the parser must assume no additional covert movement with *every* since that has happened earlier in the parse. To explain the fact that non-local ACD resolution is less difficult with *every* as well we hypothesize that the second step of QR to a position above the matrix VP_1 is easier in the case of *every*, perhaps because the object needs to be moved less far than in the case of *the*.

The results of Experiment 2b are similarly explained if we assume that *wh*-phrases are quantifiers that must QR to the nearest propositional node for interpretation as soon as they are encountered by the parser, but that no such movement is assumed in the case of the definite article *the*. As a result, covert movement must always be assumed to take place at the point of ACD resolution in *the* case of the but not in the case of *which*: when a *small ellipsis* (marked with *did*) is encountered, the parser must assume no additional covert movement with *every* since that has happened earlier in the parse. As in the case of *every* in Experiment 2a, we find that non-local ACD resolution is less difficult with *which* than with *the*. This is explained in the same way as for *every*: we hypothesize that the second step of QR to a position above the matrix VP_1 is easier in the case of *which* because the object needs to be moved less far than in the case of the.

The results of Experiment 2 thus confirm that Experiment 1 is sensitive enough to detect potential differences between determiners with regard to their interaction with ACD, and that there is no reason to suspect that participants were not processing the experimental materials with sufficient depth. Here again, we find similar accuracy rates on target and filler sentences as in Experiment 1, and the overall reaction times in Experiment 2 are comparable to those found in Experiment 1 (see Figure 2).

The facilitation effect found with *every* compared to the definite article *the* and the fact that parallel behavior is observed with *which* support the interpretation we have given to the results of Experiment 1. Specifically, they show that local ACD resolution with *which* is facilitated just as it is for *every*. The facilitation effect with *which* is not compatible with the *wh*-phrase having been processed in-situ when it was encountered by the parser, as we would then predict no effect of *determiner* in Experiment 2b. Instead, the results are consistent with *which* being QRed *locally* to a position above the embedded VP_2, just like traditional quantificational determiners. Under this approach, *which* is expected to facilitate ACD resolution to a similar extent as *every*, and this is indeed the result of Experiment 2b. This leads us to adopt a new approach to the interpretation of *wh*-in-situ, repeated in (20).

(20) **The *partial movement* approach**
A *wh*-phrase must be interpreted at a position with propositional type at LF.

There is, however, an alternative interpretation of the results of Experiments 1-2: it is possible that Experiments 1-2 do not show lack of sufficient covert movement with *every*

of Experiment 3 below will provide us with the missing evidence to make this claim in this paper here as well, and we will return to this point after introducing that experiment.

and *which* in the *large ellipsis* (was) condition, but instead only an effect of the complexity of the antecedent. If the difference between *the* on the one hand and *every* and *which* on the other hand is not the result of a difference in QR assumed for the interpretation of these determiners, but instead is contributed by some other source,[20] then we can no longer infer from the difference between the behavior of *every* (and *which*) and the that upstream covert movement has occurred with *every* (and *which*) but not with *the*. The main effect of *ellipsis size* could be explained as an effect of the complexity of the antecedent: integrating a smaller, simpler antecedent into the structure is easier than integrating a larger, more complex antecedent. The main effect of *determiner* would be a consequence of the as yet to be identified property of the that makes ACD resolution with it difficult.

Experiment 3 will address this possible alternative interpretation of Experiments 1-2 by considering a prediction of the partial movement approach: that although *wh*-phrases need not move any further once they have been integrated into the structure—that is, following an initial QR step for *wh*-phrases in object position—they may be forced to move higher on independent grounds. This prediction allows us to distinguish between the behavior of *every* and the behavior of *which* in certain environments, where long-distance *wh*-movement may be necessary, leading us to expect a larger region in the question in which ACD facilitation effects are expected with *which* but not with *every*. If the no-movement approach sketched above is on the right track—that is, if all Experiments 1-2 are showing is a complexity effect, then we should not see an increased domain of ACD facilitation effects, because no long-distance covert movement is assumed when the parser reaches *which*. On the other hand, if the partial movement approach is on the right track, then additional covert movement must occur in the question and we expect to find facilitation effects of ACD resolution for any ellipsis that is smaller than the landing site of this extended covert movement step. Below we test this prediction and show that it is indeed borne out.

(21) **Predictions of the partial movement approach**
Wh-phrases are quantifiers that QR to the nearest propositional node for interpretation. No additional movement is required for the interpretation of a *wh*-phrase, but movement may be forced by external interpretability considerations.
Wh-movement may target other positions beside C.

3.3 Experiments 3a-b: *every* vs. *which* with interveners

As noted above, the *partial movement* approach to *wh*-in-situ predicts that, although *wh*-phrases in object position can be interpreted in-situ following an initial QR step, other factors may force further *wh*-movement. If long-distance movement can be forced, we expect to find facilitation effects of ACD resolution in a larger portion of the sentence, up to the position targeted by covert movement. One phenomenon that has been argued to force covert movement of in-situ *wh*-phrases is *intervention effects*. Importantly, this phenomenon

[20] For example, if—for whatever reasons—the processing of ACD hosted by *every* and *which* is easier than the processing of ACD hosted by *the*.

has not been argued to affect quantificational determiners like *every*, and so intervention effects allow us to make diverging predictions about the behavior of *every* and *which* and to experimentally test these predictions.

Below we give a brief introduction to the theory of intervention effects that will be assumed here. We show how intervention effects can be used in the experimental paradigm to test the predictions of the *partial movement* approach, and then present Experiments 3a-b, which use intervention effects in the paradigm of Experiment 1 and corroborate the predictions of the partial movement approach to *wh*-in-situ.

3.3.1 The theory of intervention effects

The term *intervention effect* describes a situation in which a question is rendered ungrammatical because an in-situ *wh*-phrase is c-commanded at LF by an *intervener*, for instance a focus sensitive operator such as *only* or negation. Cross-linguistically, intervention effects have been found in *wh*-fronting languages as well as in *wh*-in-situ languages, and several competing theories have been proposed to explain the phenomenon (cf. Beck, 1996, 2006; Beck and Kim, 1997; Kim, 2002; Pesetsky, 2000; Tomioka, 2007a,b; Cable, 2010; Mayr, to appear, see also Hagstrom 1998; Hoji 1985; Soh 2005).

Here we adopt Beck's (2006) approach to intervention effects, who following Pesetsky (2000), proposes that these effects are caused whenever a *wh*-phrase cannot covertly move above a potentially offending intervener and is instead forced to be interpreted in-situ using focus-alternatives. The intervener is argued to disrupt the transmission of alternatives from the *wh* to C, resulting in ungrammaticality, (22b). If, on the other hand, the *wh* is able to covertly move to a position above the intervener, the question can be assigned a convergent semantics, (22a). This state of affairs is summarized in the schema in (22), where covert movement is marked with an arrow and areas where alternatives are projected are marked with a curly arrow.[21]

(22) **The configuration of an intervention effect (Beck, 2006)**

a. ✓ [$_{CP}$ C ... *wh* ... **intervener** ... *t* ...]

b. * [$_{CP}$ C ... **intervener** ... *wh* ...]

In English, superiority-obeying questions are immune to intervention effects, but superiority-violating questions are ungrammatical whenever an intervener occurs above an in-situ *wh*-phrase (É Kiss, 1986; Pesetsky, 2000). This is illustrated in (23a-b), which employ the focus-sensitive operator only as intervener.

[21] For Beck (2006), covert movement necessarily targets the interrogative complementizer. That is, Beck adopts the traditional all-or-nothing view of covert movement. However, in principle all that is necessary for the *wh*-phrase to be interpretable in Becks theory is for it to move above the intervener. This is compatible with a smaller movement step under the partial movement approach, as schematized in (22a).

(23) **Intervention effects only target superiority-violating questions**

a. *Which student* did **only** Fred introduce ___ to *which professor*? Sup.-obeying

b. * *Which professor* did **only** Fred introduce *which student* to ___? Sup.-violating

Pesetsky (2000) and Beck (2006) argue that in superiority-obeying questions, the in-situ *wh* is able to covertly move to C at LF. As a result, it is above the offending intervener and hence the question is grammatical, (23a). In superiority-violating questions, on the other hand, the in-situ *wh* cannot move to C and must stay in-situ at LF and be interpreted via focus-alternatives. As a result, if an intervener occurs above the in-situ *wh*-phrase, the result is ungrammaticality, (23b).

The grammaticality of example (23a) is explained because the in-situ *wh*-phrase *which professor* is able to covertly move above the intervener at LF. Note that this movement of *which professor* targets a higher position than what is expected if no intervener is present. This is shown in (24)-(25) below, where a question with and without an intervener are contrasted. We can see that longer movement has occurred in the question with an intervener (25) than in the question that lacks an intervener, (24): In example (24), *which professor* has covertly moved above the predicate *introduce* to satisfy the interpretability requirement which forces it to QR to a propositional node for interpretation. In example (25), *which professor* undergoes covert movement above the intervener (and perhaps as far as C) in order to avoid the illicit intervention effect configuration in (22b). If *which professor* were not covertly raised above the intervener, the result would be the ungrammatical (25a) (which is identical to (24) except for the presence of the intervener). As before, dashed arrows represent covert movement and curly arrows represent areas in which focus-alternatives are computed. For simplicity, we do not draw arrows to represent the overt movement in these LFs.

(24) **LF of multiple question under the partial movement approach**

Which student did Fred introduce ___ to *which professor*?

[[*which student*]$_1$ [C [$_{TP}$ ... t$_1$ ... [*which professor*]$_2$ [$_{VP}$ introduce ... t$_2$]]]]

(25) **LF of question with intervener under the partial movement approach**

Which student did **only** Fred introduce ___ to *which professor*?

a. * [[*which student*]$_1$ [C [$_{TP}$ ... **intervener** t$_1$ [*which professor*]$_2$ [$_{VP}$ introduce ... t$_2$]]]]

b. [[*which student*]$_1$ [C [$_{TP}$ ... [*which prof.*]$_2$ **intervener** t$_1$ t$_2$ [$_{VP}$ introduce ... t$_2$]]]]

We thus predict that the presence of an intervener in a question can force additional covert movement of *wh*-phrases that could otherwise be interpreted without movement following their QR step. The movement must be at least as high as the intervener, but need not target C. Hence, we expect the presence and placement of an intervener in a question to affect ACD resolution in that question. The intervener marks the scope of the necessary covert movement in the question: the *wh*-phrase must move at least as high as the intervener in order to escape intervention. We thus expect to find facilitation of ACD resolution if the ellipsis is smaller than the movement required by the intervener. On the other hand, no additional movement step is predicted to occur in the case of the quantificational determiner *every*, because interveners do not interact with traditional quantifiers. Consequently, no additional facilitation of ACD resolution is expected when an intervener occurs in the context of *every*. Thus, we predict no effect of the presence and placement of an intervener in sentences with ACD hosted by *every*. Testing this prediction will be the goal of Experiments 3a-b.

Experiment 3a-b will use the focus-sensitive intervener ***also***. Although previous work on English has not used this intervener, it is known to be focus-sensitive (Beaver and Clark, 2008, a.o.) and has been argued to act as an intervener in other languages (Kim, 2002; Beck, 2006, a.o.). We argue that it acts as an intervener in English as well, exhibiting the same grammaticality paradigm as known interveners such as ***only*** and ***even***, where a superiority-obeying question with ***also*** above the in-situ *wh*-phrase is grammatical, (27a), but a superiority-violating question with ***also*** above the in-situ *wh*-phrase is ungrammatical, (27b, cf. example (23)). Compare this with the baselines in (26), which are minimally different in that they do not contain an intervener. Here, both the superiority-obeying question (26a) and the superiority-violating question (26b) are grammatical.[22]

(26) **Baseline: sup.-obeying and sup-violating questions both grammatical**

I know that the teacher punished some students last week. Do you know...

a. *which punishment* the teacher gave __ to *which student* on Friday?

b. *which student* the teacher gave *which punishment* to __ on Friday?

(27) ***Also* is an intervener in English**

I know that the teacher punished some students on Thursday. Do you know...

a. *which punishment* the teacher ***also*** gave __ to *which student* on Friday?

b. * *which student* the teacher ***also*** gave *which punishment* to __ on Friday?

3.3.2 Design

Experiment 3 is an expansion of Experiment 1, adding interveners to the questions. Three factors will be crossed: (a) *determiner*: whether the embedded question contained the quantificational determiner *every*, yielding a simplex *wh*-question, or a second *wh*-phrase, yielding a multiple *wh*-question; (b) *ellipsis size*: whether the sentence contained a *small ellipsis* marked by <u>*did*</u>, where the antecedent of the ACD site is the embedded VP_2, or *large ellipsis]* marked by <u>*was*</u>, where the antecedent of the ACD site is the matrix VP_1; and (c) *position of also*: whether the intervener *also* is *low* and occurs above the embedded VP_2, or *high* and occurs above the matrix VP_1.

[22] We note that judgments regarding intervention effects are notoriously tricky. The question must be read with a supporting context, so that it receives a pair-list interpretation and not a single-pair interpretation. Many speakers additionally find the judgment crisper in an embedded context compared to a matrix question.

To simplify the design and the analysis of the results, Experiment 3 is divided into two sub-experiments, each using just one determiner, *every* or *which*. Sample items for Experiments 3a-b are given in (28)-(29). See the Appendix for a full list of the materials.

(28) **Sample target item in Experiment 3a (*every*)**[23]

The conductor asked *which soloist* was ...

a. $[_{VP1}$ **also** willing to $[_{VP2}$ perform every concerto that the brilliant protege did ... *(sm ellipsis)*
b. $[_{VP1}$ willing to $[_{VP2}$ **also** perform every concerto that the brilliant protege did ... *(sm ellipsis)*
c. $[_{VP1}$ **also** willing to $[_{VP2}$ perform every concerto that the brilliant protege was ... *(lg ellipsis)*
d. $[_{VP1}$ willing to $[_{VP2}$ **also** perform every concerto that the brilliant protege was ... *(lg ellipsis)*

...and restructured the rehearsal accordingly.

(29) **Sample target item in Experiment 3b (*which*)**

The conductor asked *which soloist* was ...

a. $[_{VP1}$ **also** willing to $[_{VP2}$ perform which concerto that the brilliant protege did ... *(sm ellipsis)*
b. $[_{VP1}$ willing to $[_{VP2}$ **also** perform which concerto that the brilliant protege did ... *(sm ellipsis)*
c. $[_{VP1}$ **also** willing to $[_{VP2}$ perform which concerto that the brilliant protege was ... *(lg ellipsis)*
d. $[_{VP1}$ willing to $[_{VP2}$ **also** perform which concerto that the brilliant protege was ... *(lg ellipsis)*

...and restructured the rehearsal accordingly.

Experiment 3 contained the same 28 target sentences from Experiment 1, along with the same 48 filler items. The items were minimally changed to add the intervener *also* in the appropriate places. No changes were made to the comprehension questions.

3.3.3 Predictions

As sketched above, we expect interveners to interact with *wh*-phrases and force movement of the in-situ *wh*-phrase to a position above the intervener. Following our assumptions about the parser, we expect it to perform the smallest movement possible, that is to target the first interpretable position above the intervener and no higher. Hence, in the *low also* condition, we expect *wh*-movement to target a position above *also* but below VP_1, while in the *high also* condition we expect long distance *wh*-movement above also and thus above VP_1. We do not expect interveners to interact with *every*, as conventional quantifiers do not interact with focus interveners, and hence we expect *every* to undergo a small QR step and not to move any further until the need for long-distance movement is apparent after reaching the ACD site marked by *was*.

[23] We note that there are several choices for what element in (28)-(29) might be chosen by a reader to be the associate of *also*. One natural choice is *protege*, which contrasts with the *soloist* occurring higher in the sentence. Other options native speakers have reported to us are possible choices are *concerto* and the verb *perform*. The actual choice made by readers is immaterial to our predictions for this experiment: all that matters is that *also* acts as a focus-sensitive operator, forcing movement above it in the case of *which* but not in the case of *every*.

For Experiment 3a we expect to replicate the results of Experiment 1, since interveners should not affect the parsing of sentences with *every*. That is, we expect to find a main effect of *ellipsis size* and, crucially, no interaction with the *placement of also*. The parser assumes covert movement as soon as it encounters *every* to a local position just above the embedded VP_2. This position is high enough to preemptively undo antecedent containment in the case of *small ellipsis* (28a-b) but not in the case of the *large ellipsis* (28c-d). Hence, no particular processing cost should be associated with the *reanalysis* step of ACD resolution at the ellipsis site in the *small ellipsis* conditions, because no additional movement is required at the gap site in order to resolve ACD in this sentence. All that the parser must do is identify an appropriate antecedent for the ellipsis, fill it into the gap and compute the resulting meaning. In the case of the *large ellipsis*, however, the covert movement that was assumed following the processing of *every* is not sufficient: following this movement, the missing VP is still contained inside its antecedent. Hence, when the auxiliary *was* is reached, the parser must again reanalyze the structure, covertly moving the object a second time from its position above the embedded VP_2 to a position higher than the matrix VP_1. Hence, a high processing cost should be associated with the resolution of the *large ellipsis* in (28c-d). Since the presence and position of *also* should not affect the movement of *every*, we predict no differences between the *low also* conditions (28b,d) and *high also* conditions (28a,c).

Different predictions are made in the case of Experiment 3b. Here, we expect the position of *also* to affect the amount of covert movement that the in-situ *wh*-phrase must undergo irrespective of the size of ACD.

In the *low also* conditions (29b,d), we expect the results to resemble those of Experiment 1 and of Experiment 3a. The position of *also* above the embedded VP_2 will force local movement, targeting a position above *also* in the embedded VP_2 but below the matrix VP_1. This position is high enough to preemptively undo antecedent containment in the case of *small ellipsis* (29b) but not in the case of the *large ellipsis* (29d). Consequently, we expect ACD resolution to be facilitated in the case of *small ellipsis* but not in the case of the *large ellipsis*, resulting in larger RRTs for the *was* conditions compared to the *did* condition.

In the *high also* conditions (29a,c), the position of *also* is above the matrix VP_1. As always, the parser must assume covert movement as soon as it encounters *which*. Unlike in the case of *low also*, here the movement must be non-local and target a position above the matrix VP_1. This position is high enough to preemptively undo antecedent containment both in the case of *small ellipsis* (29a) and *large ellipsis* (29c). As a result, when the parser reaches the gap site—in both ellipsis conditions—no reanalysis is necessary in order to construct an appropriate antecedent for the ellipsis. All the parser must do is find an antecedent for the ellipsis in the already constructed structure, fill it into the gap and compute the resulting meaning, but nothing more. We thus expect ACD resolution to be facilitated in both the *small ellipsis* and the *large ellipsis* conditions.

In summary, in addition to a main effect of *ellipsis size* which we expect to find in both Experiments 3a-b, we expect no effect of the *position of also* in the case of Experiment 3a (with *every*), but we do expect an effect of the *position of also* in Experiment 3b (with *which*). In particular, a *high also* should force a longer covert *wh*-movement step than a *low also*, and this additional movement is expected to create a larger region in which the facilitation of ACD resolution is expected. Both experiments contain conditions that will serve to replicate the results of the previous experiments. Furthermore this experiment will present novel data on the online processing of questions with interveners.

3.3.4 Results

243 native speakers of English participated in this study: 123 subjects participated in Experiment 3a and 120 subjects participated in Experiment 3b.[24] 27 subjects were excluded from the analysis of Experiment 3a and 25 subjects were excluded from the analysis of Experiment 3b using the same exclusion criteria specified in Experiment 1. Two target sentences and three filler sentences were excluded from the analysis of both experiments because of low accuracy (<60% across all participants).

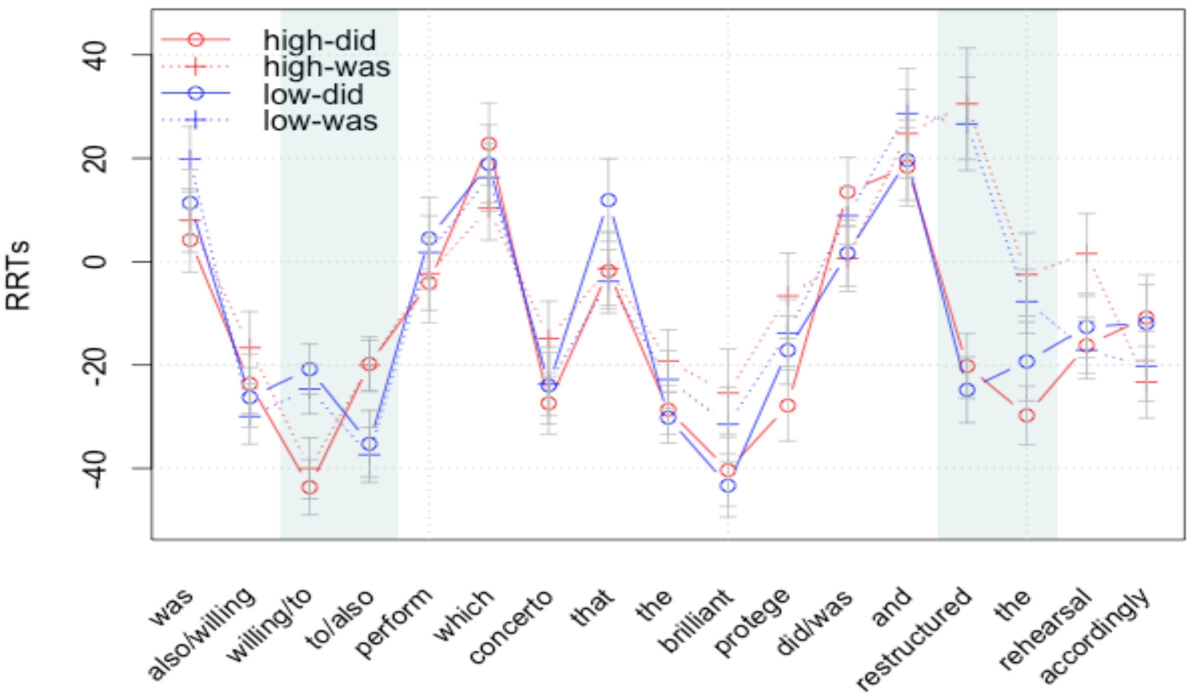

Figure 7: Residual reading times in target items in Experiment 3a

Questions across the full experiment (targets and fillers) were answered correctly 84.9% of the time across participants in Experiment 3a and 86% of the time across participants in Experiment 3b; questions for experimental items were answered correctly on 82.42% of trials in Experiment 3a and on 82.47% of the trials in Experiment 3b. The data was trimmed as described for Experiment 1 above. Overall, less than 1% of the data was excluded. Below we present first the results of Experiment 3a and then those of Experiment 3b. Figure 7

[24]The details for Experiments 3a-b represent the aggregate results from two separate replications of each experiment, requested by an anonymous reviewer in order to ensure that the results are indeed reliable.

shows the mean RRTs for the region of interest for the four target conditions in Experiment 3a. Recall that Experiment 3a contained *every* as the determiner heading the object relative clause in all target sentences.

A linear mixed effects model with random intercepts and slopes for subjects and random intercepts and slopes for the effect of *ellipsis size* for items was fit to the data[25]. The model predicted RRTs from the two factors of interest: *position of also* (*low*, above the embedded verb vs. *high*, above the matrix verb) and *ellipsis size* (*small ellipsis*, marked by *did*, vs. *large ellipsis*, marked by *was*). The results show a main effect of *position of also* at the third and fourth word in the region of interest (where *also* occurs in the sentences). The results additionally show a main effect of ellipsis size two and three words after the auxiliary site (log likelihood tests comparing a model with and without the predictor of interest, ps<0.05). These results are driven by the fact that the resolution of *small ellipsis* is faster than the resolution of *large ellipsis* for both the *low also* and *high also* conditions. There were no other significant effects in the data. The results of the model for the third word after the auxiliary site are summarized in Table 4.

Predictor	Coefficient	Standard Error	t value
Intercept	-28.342	11.909	-2.380
Position of also	7.449	8.282	0.900
Ellipsis size	25.073	10.653	2.354
Position of also×*Ellipsis size*	-14.070	13.034	-1.079

Table 4: Results of Experiment 3a

Next, we examine the results of Experiment 3b. Recall that in this experiment, the determiner heading the object relative clause in all four target conditions was *which*. Figure 8 shows the mean RRTs for the region of interest for the four target conditions.

A linear mixed effects model with random slopes and intercepts for subjects and items was fit to the data. The model predicted RRTs from the two factors of interest: *position of also* (*low*, above the embedded verb vs. *high*, above the matrix predicate) and *ellipsis size* (*small ellipsis*, marked by *did*, vs. *large ellipsis*, marked by *was*). The results show a main effect of *position of also* at the third and fourth word in the region of interest (where *also* occurs in the sentences). The results additionally show a main effect of *ellipsis size* two and three words after the auxiliary verb site and a main effect of the *position of also* three words after the auxiliary site (log likelihood tests, ps<0.05). The main effect of *ellipsis size* reflects the fact that the resolution of *small ellipsis* is faster than the resolution of *large ellipsis* for both *also* conditions, while the main effect of the *position of also* is caused because the processing of the *high also* conditions is faster than the processing of the *low also* conditions. There were no other significant effects in the data. The results of the model for the third word after the auxiliary site are summarized in Table 5.

[25] A more specified model with slopes for the effect of *also* for items did not converge.

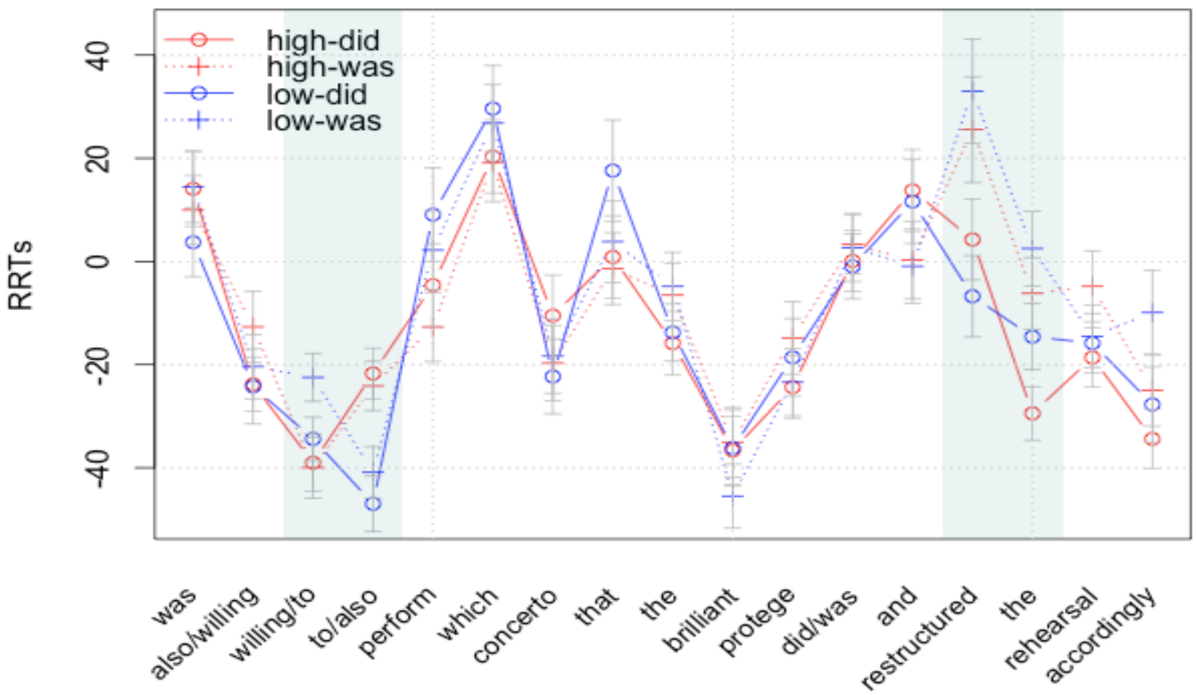

Figure 8: Residual reading times in target items in Experiment 3b

Predictor	Coefficient	Standard Error	t value
Intercept	-29.634	9.056	-3.272
Position of also	17.017	7.584	2.244
Ellipsis size	21.984	9.215	2.386
Position of also×*Ellipsis size*	-6.791	11.810	-0.575

Table 5: Results of Experiment 3b

3.3.5 Discussion

Several effects can be observed in both Experiment 3a and Experiment 3b. First, we find a similar effect of the presence of *also* on participants' behavior when the word '*also*' was read. We can take this effect to indicate that our participants were paying attention to this experimental manipulation.

Additionally, we find a main effect of *ellipsis size* in both experiments, occurring on the second and third word after the ellipsis site. This effect is more pronounced on the second word following the auxiliary verb, as can be seen in Figure 9. The graph on the left shows RRTs for sentences with an object relative clause hosted by *every* (Experiment 3a) and the graph on the right shows RRTs for sentences with an object relative clause hosted by *which* (Experiment 3b). Note that here there is no difference between the two *also* conditions in the two experiments.

In both Experiments 3a-b, we observe the main effect of *ellipsis size* not only on the second

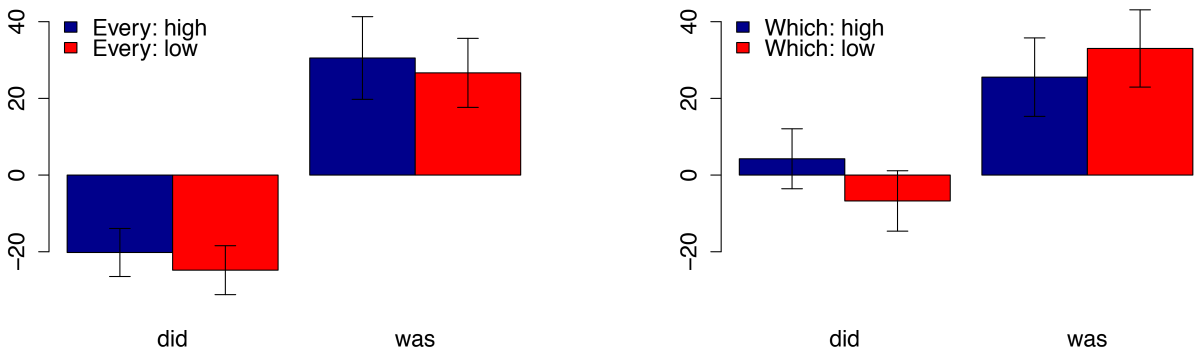

Figure 9: RRTs two words after AUX in Experiments 3a (*every*, left) and 3b (*which*, right)

word following the auxiliary verb but also on the third word. More importantly, we find that on this word, the presence and position of *also* affects the resolution of ACD differently in the two experiments. Specifically, *also* does not have an effect in Experiment 3a, but in the case of Experiment 3b, we find a main effect of *position of also* in addition to the main effect of *ellipsis size*. To see this more closely, consider Figure 10, which compares the behavior of the four target conditions in Experiments 3a-b three words after the auxiliary verb. The graph on the left shows RRTs for sentences with an object relative clause hosted by *every* (Experiment 3a) and the graph on the right shows RRTs for sentences with an object relative clause hosted by *which* (Experiment 3b).

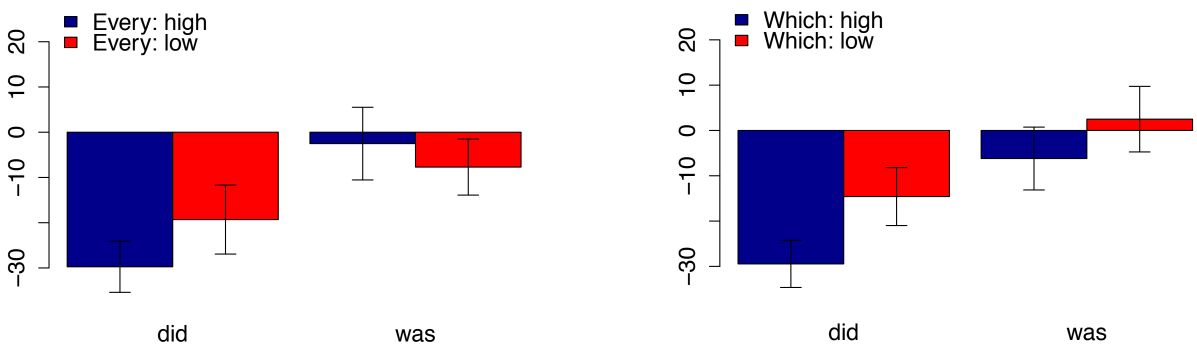

Figure 10: RRTs three words after AUX in Experiments 3a (*every*, left) and 3b (*which*, right)

The results of Experiment 3a exhibit parallel behavior for the two *also* conditions: the only effect here is that of the *ellipsis size*: *small ellipsis* (with did) is processed faster than *large ellipsis* (with was). In Experiment 3b, on the other hand, we find a main effect of *position of also* in addition to a main effect of *ellipsis size*. In particular, we find that the *high also* condition is processed faster than the *low also* condition across both *ellipsis* conditions.

The main effect of *position of also* in Experiment 3b, crucially exhibiting a facilitation effect of non-local ACD resolution with *high also* (i.e. of the was-*high also* condition) so that it is processed at a similar speed to that of the *local* ACD with *low also* (i.e. of the did-*low also* condition), is consistent with the smallest movement approach. Specifically, if interpretability requirements force long-distance covert *wh*-movement, we expect ACD to be facilitated in the entire movement domain. In Experiment 3b, the *high also* forces *wh*-movement above it and as a result, antecedent containment is preemptively undone not only in the case of *small ellipsis* but also in the case of *large ellipsis*. When the parser reaches the gap site in both conditions, all it has to do is find an appropriate antecedent for the ellipsis and nothing more. This should translate into a facilitation effect both for the *small ellipsis* (marked with <u>*did*</u>) and for the *large ellipsis* (marked with <u>*was*</u>) for sentences in the *high also* condition.

The effect of *ellipsis size* found in Experiments 3a-b represents the complexity of the antecedent effect, which is found here as well as in all the other experiments presented in this paper: although an intervener may force movement that preemptively undoes antecedent containment, resolving the ellipsis to a larger verbal complex is nonetheless more difficult than resolving it to a smaller, more local one. The main effect thus reflects the fact that composing a smaller more local VP (e.g., *perform*) into the structure is easier than composing a larger, more complex VP (e.g. *willing to perform*).

4 General discussion and conclusion

The results of Experiments 1-3 shed light on the interaction between properties of in-situ *wh*-phrases and the resolution of Antecedent Contained Deletion. More specifically, our findings suggest the following distribution at LF: in-situ *wh*-phrases cannot be interpreted in their base position, but also do not necessarily move to C for interpretation. Instead, they can be interpreted at any propositional node in the structure, just like regular quantifiers. Unlike regular quantifiers, however, in-situ *wh*-phrases are subject to intervention effects. Thus, the presence of an element like *also*, which projects a domain of intervention, can force in-situ *wh*-phrases to move higher than a regular quantifier in order to escape the intervention effect.

The evidence that supports these claims comes in the form of effects that in-situ *wh*-phrases have on ACD resolution in various environments. In neutral environments, we observe that in-situ *wh*-phrases interact with ACD resolution in the same way that *every* does: relative to a baseline provided by the definite article *the*, ACD resolution is facilitated. In intervention environments, in-situ *wh*-phrases can facilitate non-local ACD resolution, while *every* can't.

To see how facilitation of ACD resolution might arise as a consequence of the position of the in-situ *wh*-phrase at LF, observe that ACD resolution involves at least three steps: (a) creating a structure in which antecedent containment is undone; (b) identifying an appropriate antecedent for the ellipsis; and (c) filling the antecedent into the gap and computation of the resulting meaning. The latter two steps are required for all cases of VP ellipsis. The former movement step—the reanalysis of the structure so as to undo antecedent containment—is only required in the case of ACD. The facilitation effects of ACD resolution that we find in our experiments are the result of movement that preemptively undoes antecedent containment in the structure, so that under certain experimental manipulations step (a) of ACD resolution need not be performed when the presence of an auxiliary verb, marking the presence of ellipsis in the structure, is detected by the parser because sufficient movement had already been assumed earlier in the parse.

Experiments 1-2 show parallel behavior of *every* and *which*: both determiners facilitate the resolution of *small ellipsis* (with *did*) but not of *large ellipsis* (with *was*) (relative to a baseline provided by *the*): resolving a larger, more complex ellipsis that takes a non-local antecedent is more difficult than resolving a smaller, less complex one, that takes a local antecedent. The facilitation effect is explained if the parser must assume a small QR step of the object DP to the nearest propositional node in order to integrate both *every* and *which* into the structure, because they are quantifiers that cannot semantically compose with the verb in-situ. This early QR step preemptively undoes antecedent containment in the case of *small ellipsis*: step (a) of ACD resolution can be avoided in this case, resulting in faster reading times. This step cannot be avoided for the *large ellipsis*, leading to higher processing costs. For *the*, no covert movement is assumed when it is encountered by the parser, because *the* can be composed as the sister of a verb in-situ. The parser assumes covert movement in the structure only when it reaches the gap site of ACD, resulting in slower reading times for both *small* and *large ellipsis* with *the*.[26]

The fact that in Experiment 3b the *high also* condition is processed at a faster rate than the parallel *low also* condition across both *ellipsis size* conditions again highlights the fact that step (a) of ACD resolution can be avoided whenever antecedent containment is preemptively undone: an intervener (here: *also*) can force long-distance *wh*-movement early in the parse of the sentence. In that case, when the gap site is reached no reanalysis is needed in order to find an appropriate antecedent for long distance ACD (as well as for the local ACD), resulting in faster reading times in those cases. We can understand these faster reading times as a facilitation effect: because sufficient movement has been assumed earlier in the parse of sentences with a *high also*, step (a) of ACD resolution can be avoided and only steps (b)-(c)—which must be performed whenever there is any kind of ellipsis in a structure—must be calculated when the auxiliary verb, indicating the presence of an ellipsis site, is reached. On the other hand, in sentences with a *low also*, sufficient movement is done earlier in the parse only in the case of the *small ellipsis* but step (a) cannot be avoided when the parser reaches the auxiliary verb in the case of the *large ellipsis*.

As we have seen, the results of Experiments 1-3 are unpredicted by the traditional approaches to the interpretation of *wh*-in-situ. Both theories incorrectly predict invariability with regard to ACD resolution, such that ellipsis resolution should either be facilitated always (the *covert movement* approach) or never (the *in-situ* approach). However, the resolution of *small ellipsis* in Experiment 1—targeting the smaller VP in the sentence—was facilitated, but the *large ellipsis*—targeting a higher VP—incurred a high processing cost. The fact that ellipsis whose resolution requires non-local movement of the in-situ *wh*-phrase was not

[26] These results are consistent with the results of Xiang et al. (to appear), who compare the processing of in-situ *wh*-phrases to non-*wh* counterparts in Mandarin Chinese using a Speed-Accuracy Tradeoff experiment. As Mandarin is a *wh*-in-situ language, this study was able to compare simplex questions to minimally different sentences that did not contain a *wh*-phrase. Xiang et al. (to appear) observe a processing cost involved with the interpretation of in-situ *wh*-phrases which they argue may be attributable to covert movement. However, we note that Xiang et al. (to appear) do not rule out the possibility of alternative mechanism for the interpretation of *wh*-phrases in their experiment, which do not involve movement. These mechanisms will not be able to explain the data presented here, as discussed above.

facilitated in Experiment 1 shows that the *wh*-phrase need not and in fact does not move to C immediately upon integration into the structure. The fact that we see an increased effect of ACD facilitation with *which* compared to *the* in Experiment 2 confirms that *which* is not in situ at LF but instead patterning with *every* and undergoing a small QR step. This shows that the in-situ approach to *wh*-in-situ also cannot be correct.

To resolve this apparent impasse we have proposed that *wh*-phrases are quantifiers that must minimally QR covertly to the first propositional node in the structure to resolve a type-mismatch, much like conventional quantifiers such as *every*. We furthermore proposed the *partial movement* approach. This approach can be seen as an amendment to the in-situ approach: *wh*-phrases must move for basic structure-building reasons and interpretability, but they do not move any more than is needed for these external reasons. Once a *wh*-phrase is in an interpretable position, it can make its contribution to the interrogative semantics without moving to C. As a consequence, we require a theory of interrogative syntax/semantics that allows in-situ *wh*-phrases to be interpreted in positions other than C, and immediately below C as well.[27]

Experiment 3 corroborated an important prediction of the *partial movement* approach: that it should be possible to distinguish the behavior of *which* from that of *every*, and in particular that if a *wh*-phrase is forced to move even higher than its QRed position for interpretation, we should find facilitation effects in the entire domain of movement. Experiment 3 tested this prediction by using intervention effects, which have been argued to require movement of *wh*-phrases above an intervener for interpretation, but do not affect the behavior of other quantifiers such as *every*. We argued that *also* is an intervener in English and showed that, indeed, when *also* forces non-local movement of an in-situ *wh*-phrase, we see facilitation effects in ACD resolution of local, and crucially also of non-local ACD. The sensitivity of *which*, and the insensitivity of *every*, to the same manipulation show that *also* does not simply act as a scope marker for covert movement: such a proposal would incorrectly predict similar effects on *every* and *which*. Instead, we see *also* affecting only the *wh*-phrase but not the quantifier, consistent with the predictions of the intervention effect theory (Beck 2006) and the predictions of the *partial movement* approach.[28]

If the *partial movement* approach to *wh*-in-situ is on the right track, traditional approaches to interrogative syntax/semantics cannot be correct. *Wh*-phrases cannot be interpreted where they are pronounced, as in-situ approaches would have it, but they also need not move to C for their interpretation, as covert movement approaches claim. Instead, *wh*-phrases may remain in their lowest interpretable position, and from there make their contribution to interrogative semantics without any further movement.

[27]The development of such a theory goes beyond the scope of the present paper. See (Cable, 2007, 2010) for a proposal that contains the ingredients to interpret structures like we propose.

[28]We note that as a consequence, any theory of intervention effects that derives intervention without any covert movement faces difficulties in explaining the results of Experiment 3.

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Appendix: Materials for Experiments 1-3

Below is the full of items used in Experiments 1-3. The same item paradigms were used in all three experiments, with different choices of determiner and placement/position of *also* as described in the body of the paper. In short: Experiments 1 and 3 compared the determiners *every* and *which*, while Experiment 2 compared the determiners *the* and *every*. Experiment 3 compared the behavior of a *high* and a *low* placement of *also*, while Experiments 1-2 did not contain *also*. Recall that in all experiments, the sentences were presented on two lines, with the line break always placed immediately following the verbal complex.

1. The orderly learned which doctor was (also) planning to (also) monitor *the/every/which* patient that the duty nurse *did*/*was* and immediately updated the charts.
2. The principal determined which instructor was (also) able to (also) teach *the/every/which* class that the substitute teacher *did*/*was* and accordingly finalized the schedule.
3. The conductor asked which soloist was (also) willing to (also) play *the/every/which* piece that the brilliant protege *did*/*was* and restructured the rehearsal accordingly.
4. The coordinator learned which tutor was (also) scheduled to (also) teach *the/every/which* topic that the Physics professor *did*/*was* and assigned them to classrooms.
5. The prosecutor asked which witness was (also) told to (also) discredit *the/every/which* defendant that the corrupt detective *did*/*was* but only one witness revealed anything.
6. The teacher found_out which student was (also) eager to (also) attend *the/every/which* trip that the class president *did*/*was* and organized the field trips accordingly.
7. The detective found_out which guard was (also) willing to (also) hassle *the/every/which* prisoner that the sadistic warden *did*/*was* and included the names in his report.
8. The analyst predicted which investor was (also) prepared to (also) buy *the/every/which* stock that the hedge fund *did*/*was* and then sent $a_m$emo to the bank management.
9. The realtor asked which trainee was able to (also) show *the/every/which* property that the experienced secretary *did*/*was* but nobody was (also) available that weekend.
10. The carpenter asked which apprentice was (also) qualified to (also) use *the/every/which* technique that the licensed electrician *did*/*was* and then assigned personnel to projects.
11. The choreographer determined which dancer was (also) ready to (also) perform *the/every/which* dance_routine that the Russian ballerina *did*/*was* and then started the dance recital.
12. The organizers found_out which announcer was (also) willing to (also) cover *the/every/which* game that the notorious commentator *did*/*was* and then finalized the broadcasting schedule.

13. The librarian learned which teacher was (also) planning to (also) borrow *the*/*every*/*which* book that the visiting scholar did/was and accordingly shortened the loan periods.
14. The attorney clarified which witness was (also) supposed to (also) support *the*/*every*/*which* alibi that the undercover informant did/was and then gave his closing argument.
15. The dispatcher clarified which apprentice was (also) scheduled to (also) accompany *the*/*every*/*which* crew that the experienced engineer did/was and sent the crews on their way.
16. The programmer realized which update was (also) certain to (also) solve *the*/*every*/*which* problem that the old software did/was but surprisingly decided not to tell anyone.
17. The focus-group explained which discount was (also) likely to (also) attract *the*/*every*/*which* demographic that the Spring sale did/was and then several TV ads were launched.
18. The secretary found_out which professor was (also) going to (also) question *the*/*every*/*which* student that the disciplinary committee did/was and then scheduled the hearings.
19. The general forgot which unit was (also) scheduled to (also) attack *the*/*every*/*which* target that the nuclear submarine did/was and sent a messenger to headquarters.
20. The biologist discovered which reptile was (also) likely to (also) have *the*/*every*/*which* gene that the Tyrannosaurus Rex did/was and proposed additional tests.
21. The admiral specified which ship was (also) ordered to (also) attack *the*/*every*/*which* position that the navy jet did/was and then the joint army-navy exercise began.
22. The engineer explained which apprentice was (also) asked to (also) service *the*/*every*/*which* engine that the sick crew_member did/was and then called the train company.
23. The colonel explained which officer was (also) ordered to (also) interrogate *the*/*every*/*which* prisoner that the CIA agent did/was and then described what methods not to use.
24. The log showed which detective was (also) sent to (also) arrest *the*/*every*/*which* suspect that the FBI agent did/was and additionally where the arrest took place.
25. The detective discovered which mobster was (also) about to (also) blackmail *the*/*every*/*which* business that the street gang did/was and immediately informed his superiors.
26. The sheriff knew which marshal was (also) excited to (also) chase *the*/*every*/*which* fugitive that the state police did/was but doubted that the fugitives would be caught.
27. The scientist discovered which antibody was (also) likely to (also) attack *the*/*every*/*which* virus that the standard medication did/was but needed funding to complete her study.
28. The warden guessed which inmate was (also) trying to (also) smuggle *the*/*every*/*which* contraband that the corrupt guard did/was and therefore intensified the security screens.