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Quantifiers and discourse processing

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Abstract

Quantifiers are ubiquitous in natural language and, in addition to providing information about quantity, they serve important discourse functions. We outline several theoretical accounts of the functions that quantifiers perform in a discourse and the factors governing their interpretation, focusing on two specific topics that have received substantial attention from researchers working in linguistics and psychology. The first topic concerns the interpretation of pronominal anaphora in different quantification contexts, and we review evidence showing that the focusing effects of positive and negative quantifiers licence different patterns of pronominal reference. The second topic concerns the interpretation of quantifiers that function as anaphors in a discourse, and we consider recent experimental evidence in relation to two current and highly influential theories of semantic interpretation.

Quantifiers are ubiquitous in natural language, and include expressions such as *some*, *all*, *most*, *none*, *a few*, *few*, *a large number*, *a small proportion*, *lots*, and *a significant amount*. The most obvious function of these expressions is to convey information about an amount or a proportion. However, as should become clear in this review, quantifiers have other characteristics, and serve important functions in discourse, that make them an important subject of linguistic and psychological research.

Quantification is a central topic in formal semantics research (e.g., Barwise & Cooper, 1981; Kamp & Reyle, 1993; Montague, 1973; Partee, ter Meulen, & Wall, 1993), which aims to provide an account of the syntax and semantics of natural language quantifiers using mathematical techniques drawn from formal logic and set theory. The approach is strongly influenced by a series of papers from the 1980s that provided a general mathematical framework for describing the properties of natural language quantifiers and that has since become known as *Generalised Quantifier Theory* (GQT, Barwise & Cooper, 1981; van Bentham, 1986; Keenan & Stavi, 1986; see also Montague 1973). The aim of GQT was to provide a formal set-theoretic account of semantic properties that are universal to natural language quantifiers. Such properties include *conservativity*, which requires that the truth of a quantified statement depends only on an evaluation of individuals denoted by its first argument (which is also called the domain of quantification). More simply, this means that in order to determine whether "*all of the students were at the lecture*" is true it is necessary to check only the location of the students and not, for example, the whereabouts of the professors. Another universal property of quantifiers that we will consider in more detail shortly is *monotonicity*, which refers to the patterns of logical inference licensed by different quantifiers.

By contrast with the emphasis placed on quantification in formal semantics, there is much less research into quantification in psychology. Indeed, what psychological research exists has been concerned primarily with deductive reasoning (and for a review see, e.g., Johnson-Laird & Byrne, 1991; but see also Geurts, 2003, for an approach to syllogistic reasoning based on formal semantics), and the acquisition of the meaning of logical quantifiers (e.g., Brooks & Braine, 1996; Bucci, 1978; Donaldson & Lloyd, 1974; Noveck, 2001). Other more applied research has attempted to determine the exact amount or proportion that people have in mind when using particular quantifiers (for a review, see Clark, 1990), with the aim of improving risk communication (e.g., Bass, Cascio, & O'Conner, 1974; Beyth-Marom, 1982; Calman, 1996; Renooij & Witteman, 1999; but see Moxey & Sanford, 2000, Sanford & Moxey, 2003) and the calibration of psychometric tools (e.g., Bradburn & Miles, 1979; Wanke, 2002; Wright, Gaskell, & O'Muircheartaigh, 1994, 1997). However, it has proven difficult to establish a precise mapping between quantifiers and actual quantities, largely because the meaning of natural language quantifiers is vague and language users do not agree on the specific amount denoted by a particular quantifier. Moreover, the task is complicated further by the finding that the amount expressed by a quantifier is highly context dependent (e.g., Bass et al., 1974; Hormann, 1983; Moxey & Sanford, 1993a).

The focus of the present article is on research investigating the function quantifiers serve in a discourse. This research has been informed by, but is not always in agreement with, linguistic theory. We focus on two specific topics that have received substantial attention. The first concerns the processing of *complement anaphora*, and we will review research showing that quantifiers license different patterns of pronominal reference. The second is a closely related topic concerning situations in which quantifiers themselves act as anaphors. Here we will outline

the theoretical claims of two current accounts of semantic interpretation and consider relevant experimental evidence. Inevitably, space limitations mean that we are unable to address other important topics, including research into the processing of scope ambiguities that often occur for sentences that contain two or more quantifiers (Anderson, 2006; Filik, Paterson, & Liversedge, 2004; Kurtzman & MacDonald, 1993; Paterson, Filik, & Liversedge, 2008; Tunstall, 1999; Villalta, 2003; see also Frazier, Pacht, & Rayner, 1999), and the effects of quantifier complexity on cognitive processing loads (e.g., Warren & Gibson, 2002), or the large volume of research that has examined the acquisition of quantifier syntax and semantics (e.g., Brooks & Braine, 1996; Bucci, 1978; Donaldson & Lloyd, 1974; Noveck, 2001; and for recent reviews, see Crain & Thornton, 2006; Geurts, 2003; Lidz & Musolino, 2003).

In providing this review, we will attempt to integrate research from both linguistic and psycholinguistic traditions. However, it is important to note that the two approaches often employ different methods and are often concerned with different issues. Within a broad linguistics tradition, the emphasis has been to determine the characteristics of language by, for example, providing a classification of the form and function of different natural language expressions, often based on expert analysis of the acceptability and meaning of example utterances. By contrast, psycholinguists have tended to focus on what interpretations are actually given to utterances and the nature of the cognitive and brain processes that are responsible for language understanding. Much of this research is experimental in nature and involves collecting data from participants who generally are naïve about the topic under investigation. A common approach has included using acceptability judgement tasks or tasks in which participants provide written completions to sentence fragments, sometimes in circumstances in which the task is time-constrained, in order to determine the preferred analysis of an expression. In addition, other

methods such as self-paced reading and the analysis of eye movements while reading have been used to provide insights into the real-time processing of language (see Rayner, 1998, for a review of eye movement research). More recent research has begun to reveal the neural correlates underlying language processing, for example, by using electroencephalography (EEG) to measure electrical activity in the brain (for a recent review, see Kutas et al., 2006). In this review we will take care not to value one approach over another, since it seems clear that approaches taken by linguists and psycholinguists can be complementary, by providing a classification of the form and function of natural language expressions, and also revealing how these expressions are actually interpreted during comprehension and production.

Complement anaphora

The first issue we consider concerns the relationship between quantification and anaphora. In particular, we will examine how quantification influences the ease with which a pronominal anaphor, such as *they*, can refer to different discourse referents. To introduce this issue, consider how the meaning of the sentence in (1), which contains the quantifier *many*, can be represented in terms of several different discourse referents.

1. Many of the students attended the lecture.

The first of these referents is the set of students that the quantifier operates upon. Although this could be the set of all students (in the entire Universe), it is much more likely to be understood to be a contextually relevant set of students (e.g., Westerståhl, 1985), such as those students enrolled on a particular class at a particular university. We will follow other researchers (e.g., Nouwen, 2008) in referring to this set as the maximal set (or maxset). The sentence in (1) can also be thought of in terms of those students who were actually at the lecture and, following

Moxey and Sanford (1987), we will call this set the reference set (or refset). Finally, we might choose to consider the students who were absent from the lecture and, again following Moxey and Sanford, we will refer to this set as the Complement set (or compset).

A widespread assumption within formal semantics research is that not all of these sets are included by default as part of the representation of the discourse. In particular, it is widely argued that the compset is not automatically represented and, consequently, that this set cannot be referred to using a pronominal anaphor. This claim is exemplified by the approach taken within Discourse Representation Theory (DRT; Kamp & Reyle, 1993), where is it argued that only the maxset and other explicitly introduced subsets are included within a discourse representation, as this is sufficient for a truth-functional semantic account of quantification (see also Corblin, 1996; Kibble, 1997, Percus, Gibson, & Tunstall, 1997). When applied to the example in (1), the approach assumes that along with the maxset of students (enrolled on a particular course at a particular university), only the refset of students who actually went to the lecture is represented. Thus, it is assumed that the compset of students who were absent from the lecture does not form part of the discourse representation. Indeed, a fundamental assumption of DRT is that the construction of a discourse representation does not employ an operation corresponding to set-subtraction, in which the maxset minus the refset comes to be represented, and consequently that the compset is not available as a discourse referent unless it is explicitly mentioned. This phenomenon is shown very clearly by the well-known "marbles" example in (2), where the follow-up sentence headed by *they* is infelicitous, as it refers to a set of two marbles that can only be derived by a process of set-subtraction.

2. Eight of the ten marbles are in the bag. They are under the table.

Pronominal reference to the compset has been widely termed *complement anaphora*, and the standard view that this form of reference is not possible has been challenged most directly in research by Moxey and Sanford and their colleagues (e.g., Filik, Moxey, & Leuthold, 2009; Moxey, 2006; Moxey, Filik, & Paterson, 2009; Moxey & Sanford, 1987; 1993a, 1993b; Moxey, Sanford, & Dawydiak, 2001; Paterson, Sanford, Moxey, & Dawydiak, 1998; Sanford, Dawydiak, & Moxey, 2007; Sanford, Moxey, & Paterson, 1996; Sanford, Williams, & Fay, 2001). At the core of this approach are what Moxey and Sanford (1987) term quantifier focus effects. In particular, it is argued that positive quantifiers such as *some*, *a few*, and *many*, and negative quantifiers such as *not all*, *few* and *not many*, as well as communicating quantity information, have the important discourse function of providing different perspectives on this information (see also Anscombre, & Ducrot, 1976; Jarvella & Lundquist, 1994; Lundquist & Jarvella, 1994). To illustrate what this means, consider a situation in which a salesman is trying to sway the decision of a prospective car buyer. The reliability of the vehicle under discussion is likely to be an important consideration, and the contrast that exists between being told that "*a few of these cars break down*" as opposed to "*few of these cars break down*" is likely to have a major influence on the prospective buyer's decision-making. This effect appears to be due to the different perspectives that the quantifiers bring to the situation. That is, although *a few* and *few* both express a small proportion, they frame this information in different ways. In the case of *a few*, the focus of attention is very much on those cars that do break down, and in this context the choice of quantifier is unlikely to persuade a prospective buyer to make a purchase. By comparison, the quantifier *few* acts to minimise consideration of those cars that do break down and to direct attention instead onto the vast majority of cars that will have no problems. Thus, in this particular context, the choice of *few* is more persuasive.

Moxey and Sanford (1987, 1993b) explain these effects in terms of the focusing properties of quantifiers. At the heart of this account is the claim that positive and negative quantifiers focus attention onto different aspects of a reader's or hearer's discourse representation. In particular, Moxey and Sanford proposed that negative quantifiers such as *few* focus attention onto the compset, thereby ensuring that this set is represented, and that it is available as the referent of complement anaphora. Clearly, such a claim is at odds with the standard linguistic account, such as DRT, which rules out complement anaphora. Therefore, a major focus of the research undertaken by Moxey and Sanford and their colleagues has been to assess the acceptability of complement anaphora in different quantifier contexts. A variety of different experimental techniques have been used, including asking participants in experiments to read fragments of discourse such as those in (3) and (4) and to provide a written continuation of the follow-up sentence headed by *they*.

3. A few of the students attended the lecture. They…
4. Few of the students attended the lecture. They…

The standard finding is that different patterns of continuation emerge when a discourse includes a positive or negative quantifier. The example in (3) includes the positive quantifier *a few* and continuations to this fragment typically concern the refset, usually describing what members of this set did (although a small minority of continuations might instead refer to the maxset and, e.g., provide information about students in general). A typical refset-focused continuation might be "*They… listened carefully and took notes*", where *they* clearly refers to students who were actually at the lecture. Very few continuations to discourses that contain positive quantifiers will concern the compset (but see Moxey, 2006, for a notable exception to this). By comparison, continuations to sentences that contain negative quantifiers, such as *few* in

(4), are more likely to be about the compset than the refset. For instance, a typical compset-focused continuation for (4) might be "*They… decided to stay at home instead.*", where *they* cannot be interpreted as referring to the refset (or even the maxset) and must refer to the compset of students who did not go to the lecture.

Differences in the focusing properties of positive and negative quantifiers have also been shown to affect reading comprehension in studies using self-paced reading (Sanford et al., 1996, Experiment 3) and measures of eye movements while reading (e.g., Paterson et al., 1998), where it has been shown that pronominal reference to the refset is relatively easy when that set derives from a positive quantifier, but more difficult when it derives from a negative quantifier. In contrast, the processing of complement anaphora is easy following negative quantifiers, but substantially more difficult following positive quantifiers. These sorts of experiments have been conducted with a wide range of quantifiers and have shown that complement anaphora is licensed in most negative quantifier contexts. Furthermore, recent EEG research using event-related brain potentials (ERPs) has shown that complement anaphora evoke an N400 effect in positive quantifier contexts relative to negative quantifier contexts (Filik, Moxey, Sanford & Leuthold, 2009). The N400 is a negative peak in the ERP record which is regarded as an index of semantic processing, with a word that is a poor fit within the semantic or discourse context eliciting a larger N400 than one that is a good fit (see Kutas et al., 2006). Thus, ERP data provide even more evidence that complement anaphora are perceived as anomalous only in positive quantifier contexts.

One ongoing debate concerns whether complement anaphora do in fact refer to the compset or if they instead provide generalizations about the maxset while discounting the minority group that correspond to the refset (e.g., the small number of students who <u>did</u> attend

the lecture; Corblin, 1997; Geurts, 1997; Kibble 1997; Nouwen, 2003; Percus et al., 1997). That is to say, it has been argued that what may appear to be a compset-focused continuation may instead be a general statement that applies to the maxset based on what the majority of this group did. While such a formulation would permit a uniform treatment of standard refset reference and complement anaphora in formal approaches to quantification, such as DRT, it does not fit well with the observation that complement anaphora is still possible even when it is the refset that is in the majority. For instance, in the example in (5), readers will derive a large refset and a much smaller compset from the quantifier *not quite all*.

5. Not quite all of the students attended the lecture. They…

Findings from continuation studies clearly show a predominance of compset-focused continuations even for quantifiers like *not quite all* (Sanford et al., 1996). In fact, *not quite all* produces more compset-focused completions than most other compset-focusing quantifiers. Thus such examples provide strong evidence against the claim that apparent compset reference is in fact a generalisation based on the majority members of the maxset.

Another current controversy concerns whether the different focusing properties of positive and negative quantifiers are related to the distinction made in formal semantics between quantifiers that license monotone-increasing and monotone-decreasing patterns of inference (Barwise & Cooper, 1983; see also Hendriks & de Hoop, 2001; Kibble, 1997; Nowen, 2003, 2008). As already noted, GQT has identified monotonicity as an important universal property of quantifiers (e.g., Barwise & Cooper, 1983). According to this account of monotonicity, upwards entailing quantifiers, such as *a few*, license the inference that a property of a subset is also the property of the maxset. For instance, it is possible to say that "*A few students went to the lecture, in fact they all did*" because *a few* is an upwards entailing quantifier, and despite denoting a

small amount, it licenses the inference that what is being said about the subset is also true for the maxset. Note, however, that it is not acceptable to say that "*Few students went to the lecture, in fact they all did*" because *few* is a downwards entailing quantifier and does not license the same directional inference. Instead, downwards entailing quantifiers like *few* permit statements of the form "*Few students went to the lecture, in fact none did*". In this case, the quantifier allows the possibility that the refset is in fact an empty set (i.e., that no students went to the lecture).

One suggestion is that the monotone-decreasing property of negative quantifiers is responsible for licensing complement anaphora (e.g., Kibble, 1997; Nouwen, 2003). For instance, Nouwen has argued that complement anaphora is a special type of inference that requires the reader or hearer to infer the existence of a compset, and that such an inference is only possible in the context of a downwards entailing quantifier. This is based on the observation that it is only downwards entailing contexts that license the possibility of an empty refset and, by extension, also imply the existence of a compset. However, it remains to be determined whether this account of complement anaphora is reconcilable with psychological accounts of quantifier focus. For instance, recent psychological accounts, such as the Supposition-denial account have not adopted this approach (Moxey, 2006; see also Sanford et al., 2007), but have argued instead that negation in general, and negative quantifiers in particular, serve to deny states of affairs or facts that the hearer might suppose to be the case (see also Clark, 1976), and it is this function that enables compset reference.

The central tenet of this account is that negative quantifiers can give rise to both an assertion of an amount, and an implied expectation that more might have been the case. Thus "*not many of the students attended the lecture*" asserts that some small number of students came to the lecture, and implies that more were expected to do so. In this respect, the quantifier *not*

many is simultaneously presupposing, and denying, the higher expected amount. This difference between expectation and observation is referred to as a shortfall and it is this shortfall that is the focus of attention for the reader. According to the Supposition-denial account, the shortfall between what is expected and what is observed is the compset, and thus reference to the shortfall is, in effect, compset reference. Moxey (2006) provided evidence that the presence of a shortfall can influence focus effects in production (in a completions task), even in positive quantifier contexts. Furthermore, recent evidence from studies of eye movements while reading (Moxey, Filik, & Paterson, 2009) indicates that manipulating expectation can also influence quantifier focus effects during comprehension.

Anaphoric quantifiers

We turn now to our second topic, which concerns the interpretations given to quantifiers that function as anaphors, and therefore refer to things, or parts of things, from earlier in the text. Most research on this topic has revolved around the ambiguity found in short discourses like (6).

6. Five ships appeared on the horizon. Three ships were bombarded by enemy fire.

In this example, the quantifier *three ships* acts as an anaphor and must be interpreted with respect to the five ships in the first sentence. However, exactly which interpretation should be assigned is unclear, and the quantifier can be interpreted in two different ways. One possibility is that it refers to three of the five ships just mentioned. We will call this a *subset reading*, as in this case the quantifier refers to a subset of a group that was introduced earlier in the text and that is already established as a discourse referent. Another possibility is that it refers to a set of three ships that have not yet been mentioned, and we will call this a *new set reading*; as, in this case, the quantifier does not refer to an established referent but introduces a new referent into the discourse. The same ambiguity arises if a bare quantifier, such as *three*, is used in place of *three*

ships; but, in this case, the ambiguity is compounded by the reader also having to establish if the quantifier derives its meaning from *five ships* or some other antecedent phrase.

The ambiguity in (6) is of considerable interest to language researchers because its interpretation provides potentially important insights into the mechanisms underlying semantic interpretation. For instance, the ambiguity provides an important test case for the Optimality-theoretic account of semantic interpretation (Hendriks & de Hoop, 2001). According to this account, the interpretation given to an anaphor involves the optimal satisfaction of multiple "soft" constraints. These constraints take the form of general rules governing the interpretation of linguistic material that are ranked in terms of their importance, and are said to be "soft" because a constraint that is more highly ranked can override one that is lower ranking. The theory is strongly influenced by connectionist approaches to language processing (e.g., Rumelhart & McClelland., 1986; Prince & Smolensky, 2000), and in line with this approach it is envisaged that the possible interpretations of an anaphor are interpreted in parallel with respect to the relevant constraints and that the interpretation that ultimately is selected is one that optimally satisfies the constraints.

Hendriks and de Hoop (2001) outline several possible constraints on the interpretation of anaphora, including *DOAP* ("don't overlook anaphoric possibilities"), which requires that anaphoric interpretations are preferred, and a constraint called *Topicality* that imposes a preference for anaphors to refer to the current discourse topic. Of particular importance for the ambiguity in the (6) is the *Forward-directionality* constraint (see also, Van Kuppevelt, 1996), which stipulates that: "The topic range induced by the domain of quantification of a determiner (set A) is reduced to the topic range induced by the intersection of the two argument sets of this determiner (A \ B)" (Hendriks & de Hoop, 2001: p19). We can unpack this constraint as follows:

the first argument of the quantifier in the example in (7) is the set of students and the second argument is the set of persons who attended the meeting. Therefore, the intersection of the two argument sets corresponds to the set of ten students who attended the meeting. Thus, according to this constraint, there should be a preference for interpreting the quantifier *three* in (7) as referring to three of those ten students, which is the subset reading of the ambiguity.

7. Ten students attended the meeting. Three spoke.

Hendriks and de Hoop (2001) also propose that another, lower-ranked constraint called *Parellelism* comes into play when *Forward-directionality* cannot apply. This constraint governs situations in which an anaphor cannot be assigned a subset reading and must receive a new set reading, and restricts the anaphor to referring to an element in a parallel syntactic position in the preceding text. For example, this constraint specifies that the quantifier *three* in the example in (8) refers to three students (rather than professors) that were not at the meeting.

8. Ten students attended the meeting. Three didn't.

Astute readers will realize that *Forward Directionality* implies a preference for a pronominal anaphor to refer to the refset. While the theory permits complement anaphora (and see also, Nerbonne, Iida, & Ladusaw, 1990), Hendriks and De Hoop (2001) account for this form of reference along similar lines to arguments based on monotonicty (e.g., Kibble, 1997; Nowen, 2003). In particular, they propose a further constraint, called *Emptiness*, which creates a preference for pronominal anaphora to have an antecedent that refers to a non-empty set. Thus, according to their account, complement anaphora are licensed in circumstances in which the refset is an empty set.

The Minimal-Lowering account of semantic interpretation, proposed by Frazier (1999), provides an alternative account of the interpretation of the ambiguity in (6). This theory is more

directly influenced by the generative linguistic tradition (e.g., Heim & Kratzer, 1998) than the formal semantics approach to quantification. According to Frazier (1999), the preference for a subset reading of an ambiguity is attributable to a syntactic processing principle of Minimal Lowering operating at a level of linguistic analysis called Logical Form (LF) that represents the logical structure of a sentence (see May, 1985, for a discussion of Logical Form). The account requires that when a quantifier is the grammatical subject of a sentence, the sentence is ambiguous at LF between a representation in which grammatical constituents retain their surface order and one in which the sentence is transformed by "lowering" the quantifier into a new syntactic position. Following Diesing (1992), it is argued that a quantifier that is the grammatical subject of a sentence and that retains its surface position at LF is most likely to refer to a subset of an established referent, whereas a quantifier in a lowered syntactic position is more likely to introduce a new referent. The Minimal Lowering account stipulates that, for reasons of processing economy, the language processor avoids transformations that alter the syntactic arrangement of grammatical constituents at LF. Thus, according to the account, when a quantifier is the grammatical subject, an LF representation in which this expression has the same position as in the surface form of the sentence is preferred and, consequently, the quantifier is most likely to receive a subset reading.

Relevant empirical evidence comes largely from studies that have assessed the preferred interpretation of an ambiguity. At the simplest, this research has involved asking participants to indicate which reading of an ambiguity they prefer. For instance, Frazier, Clifton, Rayner, Deevy, Koh, and Bader (2005) asked participants to report the number of entities (e.g., ships) in short texts like (6) and found that participants produced responses that were consistent with a subset reading on the majority of trials, and observed similar preferences in German and Korean.

Moreover, research in which participants provide continuations to sentence fragments has revealed a preference for the subset reading of ambiguous bare quantifiers (e.g., *three*) in English and Dutch (Kaan, Dallas, & Barkley, 2007; Wijnen & Kaan, 2007), and other research has examined the phenomenon from a developmental perspective in order to assess whether children also have prefer a subset reading of the ambiguity (Mousoulidou & Paterson, 2008; Wijnen, Roeper, & van der Meulen, 2004). Research that has used measures of eye movements during reading to assess the processing of the ambiguity also indicates a preference for the subset reading (Frazier et al., 2005). However, Kaan et al. (2007) provided a different interpretation of findings they obtained in an ERP experiment. In this study, participants a series of stimuli like (9):

9. Twelve / Four flowers were put in the vase. Six had a broken stem and had to be cut short.

The first sentence of each stimulus established a discourse referent (e.g., either twelve flowers or four flowers) and the second began with a bare quantifier (e.g., *six*). Kaan et al. monitored EEG activity over the scalp during the time taken to read each sentence and observed divergence in the ERPs approximately 900-1500 ms after the quantifier was read, with greater positivity over posterior electrodes when the quantifier was incompatible with a subset reading (i.e., its cardinality was greater than that of the discourse referent). Kaan et al. proposed that this relatively late effect (that appears in the ERP waveform almost one second after the critical word is read) was due to costs associated with introducing a new referent into a discourse, and pointed to similar findings by Burkhardt (2006), who also observed a late posterior positivity for definite expressions (e.g., *the student*) that introduce new referents, as compared to definite expressions that refer to existing discourse referents (see also Filik, Sanford, & Leuthold, 2008, and Kaan & Swaab, 2003, for similar ERP findings). Kaan et al proposed, in line with Burkhardt's

explanation of her findings, that the late posterior positivity effect reflects additional integration and storage costs associated with the establishment of a new discourse referent rather than the processing consequences of a preference for a subset reading of the ambiguity. Thus, the apparent preference for a subset reading in this and other research may well relate to processing costs associated with introducing new referents into the discourse model rather than linguistic constraints on quantifier interpretation.

More recently, we have reported eye movement research that has produced results that are consistent with Kaan et al.'s findings (Paterson, Filik, Mousoulidou, Baliousis, & Moxey, 2008). An example of our stimuli is shown in Figure 1.

----------Figure 1 about here----------

Like Kaan et al. (2006), we used discourses that comprised two sentences. The first introduced a discourse referent (e.g., *two ships* or *five ships*) and the second sentence began with a quantifier (e.g., *three ships*) that could take either a subset or a new set reading depending on the cardinality of the established discourse referent. This situation was compared with one in which the stimuli included a determiner that disambiguated the quantifier in favour of either a subset reading (e.g., *Of these, three ships…*) or a new set reading (e.g., *Another three ships…*). Thus, the stimuli differed from those used by Kaan et al. (2007) in two respects. First, our stimuli used full quantifier phrases rather than a bare quantifier. But, more importantly, we examined the processing of ambiguous and unambiguous quantifiers, whereas Kaan et al. examined ambiguous quantifiers only. Therefore, unlike in the Kaan et al. study, it was possible in our experiment to determine if processing difficulty occurs when quantifiers introduce a new referent even when the quantifier is unambiguous. The key findings were that participants spent longer re-reading portions of text when the quantifier referred to a new discourse referent. Crucially, this effect

was observed for both ambiguous and unambiguous quantifiers, and therefore the effect was not simply due to a processing advantage for quantifiers that receive a subset reading. Instead, our findings were consistent with Kaan et al.'s claim that the difficulty is due to costs associated with the accommodation and storage of new referents within the reader's discourse model.

These findings, and those reported by Kaan et al. (2007) are in principle reconcilable with Hendriks and de Hoop's (2001) account, so long as the *Forward-directionality* constraint is a mechanism for avoiding costs associated with instantiating new discourse referents. However, the findings are more difficult to reconcile with the Minimal Lowering account (Frazier, 1999; Frazier et al., 2005), as it predicts that difficulty is experienced only for ambiguous quantifiers that ultimately must receive a *new set reading*, whereas our data indicate that a cost is incurred whenever a new referent is introduced, even when introduced by an unambiguous quantifier. One prospect for reconciling our findings with the Minimal Lowering account is to assume that our findings (and those reported by Kaan et al.), reflect two separate computational processes: one governing the representations computed at LF and another governing the updating of the discourse model. Ambiguous quantifiers might sustain costs at both levels of processing; by incurring a cost for the syntactic transformation that lowers the quantifier into a new position at LF and a second cost when introducing a new referent into the discourse model. By comparison, unambiguous quantifiers may incur costs only in updating the discourse model. An obvious way forward for research in this area will involve further detailed assessment of Optimality-theoretical and Minimal-lowering accounts of quantifier interpretation.

In summary, we have reviewed research into the processing and interpretation of quantifiers, focusing on two topics that are of considerable current interest in the linguistics and psycholinguistics literature. What should be clear from this review is that quantifiers are not just

about conveying quantities but serve much broader discourse functions. In particular, research into complement anaphora reveals how quantifiers can bring a particular perspective to the information they convey and so influence inferences that a reader or hearer makes. We have also shown that other research into the processing of quantifiers that function as pronominal anaphors has important consequences for the development of theories of semantic interpretation.

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Figure 1: Examples of texts used in Paterson, Filik, Mousoulidou, Baliousis, & Moxey (2008).

Ambiguous subset relation

The fishermen saw six ships appear on the horizon. Apparently, three ships had been bombarded by enemy fire.

Ambiguous new set relation

The fishermen saw two ships appear on the horizon. Apparently three ships had been bombarded by enemy fire.

Unambiguous subset relation

The fishermen saw six ships appear on the horizon. Of these, three ships had been bombarded by enemy fire.

Unambiguous new set relation

The fishermen saw two ships appear on the horizon. Another three ships had been bombarded by enemy fire.