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Complement Set Reference and Quantifiers

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Abstract

There is now very wide psychological evidence that some quantifiers license subsequent reference to subsets of the complement of the set normally open to subsequent reference. This has posed problems for some formal theories of the kinds of reference made possible by quantified sentences. This paper examines the phenomenon, its interpretation, and its limits. A process-model is suggested.

Introduction

The bulk of psycholinguistic research into anaphora has been concerned with relatively simple cases in which a pronoun refers back to an individual mentioned in the text (e.g., Haviland & Clark, 1974). However, there are many more complex cases including reference to plurals and sets, particularly where the anaphor or the antecedent expression is within the scope of quantification or negation. Such cases have been discussed in the formal semantics literature, especially by Kamp and Reyle (1993). In the present paper we shall discuss a phenomenon highlighted by the research of Moxey and Sanford (1987), in which we claimed a difference between the focus patterns induced by positive, and negative (or monotone decreasing) quantifiers. This discovery has been problematic for some interpretations of Discourse Representation Theory (DRT), and in this paper we discuss the interdisciplinary lessons that might be learned from research on this problem.

According to DRT the semantic interpretation of a piece of text is represented in a Discourse Representation Structure (DRS) which is updated with each new utterance. A DRS contains a set of discourse referents, and a set of conditions normally displayed as in (1) which represents the utterance Doug loves Carol:

(1) x y
 Doug (x)
 Carol (y)
 x loves y

DRT can explain uses of the plural pronoun where it refers to a previously mentioned set (since this would be available as a discourse referent in the DRS), or to a set which can be derived from singular entities already mentioned using the processes of summation and abstraction, which allow us to refer to Doug and Carol with *they* in the example above, for instance.

As we shall illustrate below this standard machinery within DRT is not capable of accounting for complement set anaphora. The thrust of this paper is that the understanding of the broad range of anaphoric phenomena depends upon the development of an account based on knowledge based inference.

Complement Set Reference

In several studies, Moxey and Sanford (1987; 1993a; Sanford, Moxey & Paterson, 1996) have shown that negative quantifiers give rise to diffuse patterns of reference. They presented subjects with quantified sentences, and invited them to write continuation sentences which were headed by the pronoun *They*. The results showed that for negative quantifiers (such as *few*), a high proportion of continuations appeared to refer to what Moxey and Sanford termed the Complement Set. The contrast is between (2) and (3):

- (2) A few members of parliament were at the meeting.
 They talked about the Education Bill.
- (3) Few members of parliament were at the meeting.
 They were out with their secretaries instead.

In (2), *They* refers to the MPs who were at the meeting, while in (3), it appears to refer to those MPs who were not at the meeting. Subjects reports of intended reference supported this interpretation. In example (2) where *They* refers to the subset of MPs who were at the meeting, Moxey and colleagues use the term reference subset or **refset**, while in (3) *They* refers to the complement subset or **Compset**.

The results of the studies by Moxey and her colleagues have a number of principal features. First, positive quantifiers give rise to the compset pattern only very rarely. In contrast, negative quantifiers give rise to a mixture of compset continuations and refset continuations. Thus the reference pattern for negatives is more diffuse. The second feature is that the incidence of compset reference is increased by the use of the connective *because*, as in (4):

- (4) Few members of Parliament were at the meeting
 because they.....

Thirdly, compset references occur with negative quantifiers which denote a full range of possible proportions. Thus they are just as prevalent a response to sentences including *Not quite all X* as they are to those including *Hardly any X*.

Finally, there are no systematic (reliable) differences in the incidence of apparent compset reference as a function of proportions denoted by quantifiers: An illustrative sample is shown in Table 1, (taken from Sanford et al., 1996).

Table 1: Proportions of reference types for quantifiers denoting varying proportions.

Quantifier	refset	compset	other:
A few	1.0	0	0
More than half	.90	0	.01
nearly all	.97	0	.03
Few	.27	.67	.06
Less than half	.25	.64	.11
Not quite all	.13	.63	.24

Complement Sets in Formal Analyses

Formal approaches relating quantification to anaphora range from Discourse Representation Theory (DRT; Kamp & Reyle, 1993) through to the semantics of quantifiers per se. Within DRT, only supersets and explicitly introduced subsets (corresponding to the Refset) can occur as discourse antecedents, this being sufficient for a truth-functional semantic accounts of quantifiers (e.g., Corblin, 1997; Guerts, in press; Percus, Gibson & Tunstall, 1997). There is no operation corresponding to set-subtraction in which the Superset minus the Reference set comes to be represented. Historically, the empirical support in favour of this comes from the well-known "marbles" example, where the use of *They* in (5) is infelicitous. However, *Eight of the ten* is not negative, so the example does not conflict with our own claims:

- (5) Eight of the ten marbles are in the bag. They are under the sofa.

The apparent conflict between the original Moxey and Sanford observations and this interpretation of DRT has given rise to a number of reactions. One is to deny the existence of Complement Set reference as a reality. It is perfectly well accepted that there is a more diffuse pattern of reference with negative quantifiers, but not that there is compset reference. Thus Corblin (1997) has claimed that what appears to be compset reference may be reference to a set in general. For instance, given (3), it may simply be the case that *in general*, MPs were out with their secretaries. However, we have argued in Sanford et al. (1996) that even if this may be true in some instances, it cannot be true in general, as shown by the occurrence of cases like (6) in the data:

- (6) Not quite all of the fans went to the game. They watched it on TV instead.

Here what is true of the compset cannot be true of the fans in general (since they cannot be said to be generally watching it on TV instead). In addition, Moxey and her colleagues always gave subjects the chance to choose the

superset in general as their "intended referent", and this category was rarely used.

A more sophisticated version of the generalisation argument has been put forward by Percus et al. (1997) and Guerts (in press) and is restricted to the treatment of predicates which can take a collective reading, as in (7):

- (7) Not quite all of the cows gave milk. Their unproductivity was a bad omen.

Since unproductivity is a property of the herd as a whole, it is not necessary for all or even most of the cows to be unproductive for the herd to be unproductive. If only 10% of the cows produced no milk, the herd could still be deemed unproductive. Again, while this may account for some instances of possible compset reference, it cannot account for compset reference in general, as evidenced by (6), for instance. The fact that subjects seldom checked the Set-in-general option as their intended referent applies here also. We conclude that compset reference cannot be dismissed in this way, and so cannot be accommodated within the DRT (Kamp & Reyle, 1993) framework.

Other semanticists (Kibble, 1997; Devlin, 1997) have accepted compset reference as a reality, and have tried to explain it with minor alterations to existing frameworks. Devlin suggests the introduction of a new rule into DRT, *Distraction*. This works in a similar way to abstraction, but is based on the negation of the predicate in the quantified statement, rather than on the predicate itself. After a sentence like *Few of the children left*, *Distraction* can be applied to yield the set of children who did not leave, which is a straightforward negation of the predicate. This is a simple manoeuvre admitting a complement set to the group of possible discourse entities.

Kibble (1997) takes a different approach, taking up van den Berg's (1996) proposal that monotone decreasing quantifiers can be modelled as negations of monotone increasing ones. He considers the possibility that any one monotone decreasing quantifier may have more than one monotone increasing quantifier as its counterpart. Kibble points to work by Zwarts (1996) on the relationship between sentence negation and predicate negation. Thus for example the complement of a quantifier ($-Q$) is the opposite of the quantifier itself; *less than 20%* becomes *20% or more*, and *not all* becomes *all*. This relates to Kibble's external negation, according to which (8) translates to (8'). The contradual ($Q-$) is the part of the overall set not denoted by the quantifier. For example, *less than 20%* becomes *80% or more*, *not all* becomes *some*, and so on. With this internal negation, (8) translates to (8'')

- (8) Few of the MPS were at the meeting.

(8') It is not the case that the set of MPs who came to the meeting was a set of -few of the MPs (where -few is the external negation of few).

(8'') The set of MPs who did not come to the meeting was a set few- of the MPs (where few- is the internal negation of few).

Kibble argues that internal and external negation result in statements which have the same truth conditions, but which lead to different possibilities for anaphoric reference. Thus external negation (8') might be followed by a pronoun referring to the refset or to the set of MPs generally; internal negation (8'') might be followed by a pronoun referring to the set of MPs generally or to the compset. Depending on the type of negation interpreted from (8) it is therefore possible to refer to the refset, the compset, or the set generally with a simple plural pronoun.

Problems

In our view there are two basic problems for the formal accounts outlined above. The first is that they rely on the idea that the plural pronoun *they* can refer to the compset where the compset is the overall set minus the refset. In fact there are many more possibilities:

- (9) Few football fans were at the match. They had been playing really badly recently. (one of our subjects completions from the study reported in 1987).
- (10) Few carol singers came to my door last night. They were all double glazing salesmen.

In (9) *They* refers to the football team supported by the fans (according to our subject), a referent clearly accessible from the scenario but not from the sets mentioned in the text. In (10) *They* refers to the set of people who came to my door who were not carol singers. In order to access this set we have to make use of the knowledge that carol singers are a subset of a set which came to my door. As with (9) this involves specific world knowledge.

Even if we ignore cases such as (9) and (10) where the pronoun refers to a set not directly related to the initial noun phrase, there are still problems with the idea that the compset is the overall set minus the refset. One restriction which Kibble places on internal negation is that it can only be calculated for proportional quantifiers and not numeric ones such as *less than 5*. This is because for his formal definition to work we must be able to calculate the value of the overall set minus the refset. In the experiment which we report in the next section we tested the hypothesis that subjects would produce more compset references after a proportional quantifier, such as *less than 5%* than after the equivalent numeric one, *less than 5*. The experiment included the expressions *less than 5* and *fewer than 5* both of which are considered by Kibble (1997) to rule out compset reference.

A second problem for the formal accounts above is that there are many factors, linguistic and non-linguistic which appear to influence the extent to which subjects produce compset continuations. Kibble's analysis specifies that those quantifiers which license compsets are monotone decreasing, while Devlin suggests that it will follow from quantifiers which are negative: indeed, she even suggests that it is negativity and not the property monotone decreasing which licenses compset reference.

As we have shown (e.g., table 1), compset reference is not the inevitable outcome of either negative or monotone decreasing quantifiers; sometimes refset references occur, although there is scant evidence for compsets ever occurring with positive, monotone increasing quantifiers (e.g. Moxey & Sanford, 1987). Although Kibble proposes a means by which the various subsets might be accessible for anaphoric reference, he does not explain why one quantifier leads to one type of reference more frequently than another. In the following experiment we compared the expressions listed in table 2 for compset continuations. We will thus compare absolute versus proportional quantifiers and large versus small quantifiers (since the size of the subset indicated by the quantifier is known to have some influence the frequency of compset reference). The basic expressions used in the experiment were *At most*, *No more than*, *less than* and *fewer than*. *At most* was included as Kibble (1997) has argued that it may be an example of a monotone decreasing quantifier which does not lead to focus on the compset i.e. a problem for Kibble's own account. *Less than* and *fewer than* were included to provide a baseline as well as to allow a test of whether absolute numbers produce compset references.

Experiment

Method

Subjects were 257 undergraduates at the University of Glasgow who volunteered to complete the sentences.¹ Each subject completed only 1 sentence so that they would be unaware of the variables being manipulated. Subjects were asked to complete one of the following sentences, where Q was one of the 16 quantifiers listed in table 2:

Q guests dressed up for the party

or

Q students attended the rally.

Approximately 15 subjects were presented with each quantifier. These particular sentences were chosen because they were considered to be neutral with respect to the number of guests or students one would expect to dress up or to attend.

As with previous studies subjects were invited to turn the page after completing their sentence. They were then asked to indicate the referent of the plural pronoun from their sentence by circling one of the following:

- (i) the guests who dressed up for the party (or the students who attended the rally).
- (ii) the guests who did not dress up for the party (or the students who did not attend the rally).
- (iii) the guests (or students) in general
- (iv) other

¹We would like to thank Katharine Young and Mitchell T. Wells who conducted this experiment under the supervision of the first author.

Clearly (i) corresponds to the refset; (ii) corresponds to the compset; and (iii) corresponds to the set in general. If (iv) was circled the subject was asked to specify what *They* referred to in their sentence. Two independent judges categorised sentences as above. Where the judges did not agree that the subjects use of the pronoun was consistent with the category the subject had circled, the sentence was placed in the "other" category.

Results

The results are shown in table 2.

Table 2 - The percentage of subjects who completed sentences with plural pronouns referring to the compset i.e. category (ii) completions

Expression	% Compset	% other
At most 5%	18%	82%
At most 80%	0%	100%
At most 1/4	5%	95%
At most 3/4	0%	100%
No more than 5%	54%	46%
No more than 80%	27%	73%
No more than 5	50%	50%
No more than 80	23%	77%
less than 5%	45%	55%
less than 80%	60%	40%
less than 5	25%	75%
less than 80	35%	65%
fewer than 5%	50%	50%
fewer than 80%	50%	50%
fewer than 5	36%	64%
fewer than 80	50%	50%

Given the variation evident in table 2 it was clear that at least two factors influenced our data. Chi-square comparisons carried out on the frequency of compset continuations reveal *at most* was followed by significantly fewer compset references than the others ($\chi^2=37.32$, d.f.= 3, $p<.001$) - though we should note that there were some compset references after *at most 5%* and *at most 1/4*. Proportions are more frequently followed by a compset reference compared to absolute numbers ($\chi^2=4.58$, d.f.= 1, $p<.05$). Although the difference between high and low denoting expressions was not significant in this study, the difference is in the expected direction and previous studies have shown that this can be a factor (see Moxey and Sanford 1993a).

Conclusion and Discussion

Our results indicate that *at most* leads to fewer compset references than the other quantifiers. Indeed the only two expressions which did not lead to any compset references were *at most 80%* and *at most 3/4*. The other expressions led to compset references between 5% and 60% of the time. However Kibble's (1997) conjecture that *at most* would not lead to compset reference at all is simply not correct.

It is also clear that there are more compset references when the quantifier is proportional rather than numeric. Nevertheless 24% of subject continuations after numeric quantifiers referred to the compset. Given that for Kibble compset reference is only possible through internal negation as in (8'') this data presents a problem.

While Kibble's definitions of external and internal negation do allow for some variation in what is referred to using a plural pronoun after quantified statements, his account does not explain why one negative expression causes greater focus on the compset than other negative quantifiers. Nor does it explain why the same negative quantifier is more likely to lead to focus on the compset in one situation than another. For example, Moxey and Sanford (1987) showed that connectives following quantified statements had an impact on the incidence of complement sets.

Dowty (1994) has taken a rather different approach from other formal thinkers, arguing that only positive quantifiers allow anaphora, and that monotone decreasing quantifiers do not license anaphora at all; compset reference is in Dowty's view a pragmatic phenomenon, in which a set is generated to accommodate a compset on the basis of pragmatics. The exact means by which this might occur is left open. Nevertheless it is our own view that pragmatic information is crucial to the understanding of this type of anaphora resolution. Pragmatic information may explain differences in the incidence of compset reference between compset licensing quantifiers and between interpretations of the same quantifier in different situations, and it is with this in mind that the account outlined in the following section was developed.

An Inference based account

We propose that when sentences are interpreted as parts of discourse, they initially set up patterns of inference which then give rise to sets which may be referred to. In the present case, this can be illustrated with negative quantifiers. It is recognised that negatives assert denials of suppositions (Clark, 1976), and Moxey and Sanford (1993b) showed that negative quantifiers do indeed appear to deny an expectation. For example, *not many* was shown to generate the expectation that more might well be considered reasonable, but that this was simply not the case. In terms of the pattern of inferences which is generated by a negative quantifier, we propose that the processor is set to determine why the expectation was not met. For instance, given sentence (11) the processor generates an implicit question of why so few fans went:

(11) not many fans went to the match.

In a continuation task, a subject writing a continuation to (11) might well write about what it was that affected the fans such that they did not attend the match. Given whatever reason or set of reasons the subject comes up with, focus may or may not be on the set of fans who were not there. The plural pronoun simply refers to a set of entities in focus.

When interpreting text produced by others, people expect to hear about certain things given that certain others have been introduced. Thus if I hear that *not many of the fans were at the match*, I expect to be given a reason, or perhaps a consequence for this sad state of affairs. All sorts of possible reasons, consequences, etc. might come to mind and the most likely referent for a plural pronoun will be the one most associated with these reasons or consequences.

Data which we have collected in on-line studies supports this view (Paterson, Sanford, Moxey, and Dawydiak, in press). That is, while pronouns following positive quantifiers are processed more quickly than those following negative quantifiers, mismatches are more often noticed and noticed sooner when they follow a positive quantifier. After a positive quantified statement the reasons, consequences or likely next statements all concern the refset. The refset is therefore very likely to be the referent of any plural pronoun which comes up, and the pronoun will be resolved very quickly. If it turns out that the pronoun does not make sense when used to refer to the refset as in (12), then the processor runs into trouble:

(12) A few of the MPs attended the meeting. Their absence helped the meeting run smoothly.

After a negative quantified statement the reasons, consequences and so on are much more diffuse. There may be several potential sets of people or things involved. If there are many reasons involving one particular set (e.g. the compset) then this will be a preferred referent for a pronoun, but it is much more likely that the processor will hold off on any definite resolution until the predicate of the second sentence is processed. For this reason the processor will be slower to realise when the pronoun does not refer to the compset even in a situation where compset continuations are normally produced by subjects.

Our view is also consistent with the finding that the same quantifier can vary from one situation to the other with respect to the number of compset references it generates. Thus we would argue that although (13) below might lead people to focus on reasons why the fans did not go to the match, and (14) might lead them to focus on why the children did not eat their ice-cream, the kinds of inference which become available in the interpreters head will not be the same in each case. Thus while (13) in one study produced around 60% compset continuations, (14) produced over 90% (Moxey and Sanford, 1993a). Perhaps all the reasons that subjects can think of why children do not eat ice-cream involve the set of children who did not eat it.² Given the expectation that children do eat ice-cream it would be hard to come up with a reason for not eating it in terms of those who did (they were determined to eat it?). On the other hand we do not have strong expectations about attendance at a football match since we don't know if the team is popular or if the match is an important one. The

² In fact it is quite likely that if the subjects had not been forced to continue after the plural pronoun they would have continued with "It was yucky" since this might be a common reason for not eating ice-cream.

violation indicated by the quantifier is much less convincing and people may focus on inferences which are not reasons but consequences, for example of the small number attending. This means that there is more than one set available for reference and there may be fewer compset continuations.

(13) Few fans were at the match. They...

(14) Few children ate their ice-cream. They...

All monotone decreasing expressions make assertions which could be considered denials of possible states of affairs. So, if we hear that *no more than 10 fans went to the match*, part of the pattern of inference generated might be the implicit question of why not more than 10 went. However, additional questions may well be generated. For example, why would a speaker select *10*, why not simply say *hardly any fans* instead? Following this line of reasoning we suggest that although monotone decreasing expressions lead to denials, the exact way in which they are worded is not incidental, and may well produce different patterns of inference. We propose that the strongest triggers of denial are explicit negatives and these will lead to the highest incidence of compset reference.

An analysis of the content of the continuations associated with complement set reference shows most of them to be explanations of denials of expectation. Note however that there is nothing in our account which means that compset references are dependent upon this type of continuation. Indeed we have also found compset references in situations where no explanation is made by the subject:

(15) Few of the children hated Santa Claus. They left him plenty of milk and cookies.

In (15) no norm has been violated (we do not expect children to hate Santa Claus), and so an explanation is not in order. Nevertheless the continuation concerns those children who do not hate Santa Claus - a consequence of their liking for him. In this situation a reason for violation is likely to be a reason why those who hate Santa hate him (i.e. the refset).

It is also clear from our data that quantifiers lead subjects to focus on the compset to different extents regardless of the situation. *Hardly any* leads to more compset continuations than *few* for example. In our view this is because each quantifier leads us to make a slightly different set of inferences by marking the information conveyed by the quantified statement in a slightly different way. We would predict that the degree to which some quantifiers constrain our thoughts about what will be said next varies.

Thus we would argue that the compset phenomenon is a side effect of the inferences which we are led to focus on as we process text. We would further predict that since this is the case the context of a positive quantified statement could possibly lead to compset reference. We observed one case from a recent experiment (unpublished data) where subjects were told that the text concerned nursing staff at a Geriatric hospital:

(16) Of the 400 nursing staff employed at the hospital, a few nurses appear to like children. They seem more relaxed with older people.

Our subject checked the compset category as the referent for *They*. Since we were deliberately trying to elicit compset references, we felt that subjects might misread *a few* as *few*, and so after checking the referent for *They* subjects were invited to turn the page. Without looking back they were asked to state which of the following expressions had appeared in the sentence they had completed: *a few, few, only a few, not many or hardly any*. A previous study on memory for quantifiers indicates that subjects are likely to confuse positive quantifiers with other positive quantifiers and negative quantifiers with other negative quantifiers. Hence if our subject had misread the quantifier as a negative quantifier he or she should check any but the first of the quantifiers listed. Our subject circled *a few*, indicating that the quantifier in the first statement had been read correctly. Although this was just one subject out of 20 (the other all produced refset or general continuations) we would argue that it supports our argument. Complement set reference to positives does occur, but can only be explained in terms of pragmatics.

Conclusion

The demonstration of compset reference licensed by monotone decreasing quantifiers has been considered a problem for some formal accounts of anaphora, such as Discourse Representation Theory. One response has been to claim that compset reference does not occur, rather what appears to be compset reference is really a reference to the set in general. This approach does not explain the full range of sentence types generated in continuation tasks however. Some formalists, notably Kibble (1997) and Devlin (1997) have accepted the phenomenon as real and have attempted to develop ways in which complement sets may become available within the machinery of the semantic analysis of quantifiers, and DRT respectively.

While these treatments are concerned with ways of representing the possibility of compsets, they do not explain why the incidence of compset references varies widely with quantifier types, when those quantifiers are monotone decreasing. In Kibbles' case, he argues that expressions containing numbers rather than proportions should not produce compset references. This is empirically falsified. No-one has given any serious consideration to the possibility that positive expressions could yield compsets, yet there is now a little evidence that this too is possible.

The variability of incidence of compset reference not specifically addressed by formal theories (but not incompatible with Kibbles' approach), and is illustrated dramatically in the present experiment. The Inference-Driven account which we offer assumes that the sets which become available, and in focus, are determined by fields of inference generated by the quantified statements. This can be readily illustrated with respect to negative quantifiers, and offers a framework with which the variability might be explored.

A final comment we should make is that reliance on intuition regarding the possibility of compset reference is demonstrably fallacious.

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