QUANTIFICATION, RESTRICTOR CONTENT, AND CONTRAST IN SENTENCE PROCESSING

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A recent focus of study has been the impact of quantification on sentence processing. Developing from work comparing sentences with quantified NPs and referential NPs (Warren & Gibson, 2002) and work looking at quantifier restrictor weight (Warren, 2003), the current self-paced reading studies address issues of quantifier restrictor weight and quantifier type in regards to contrast set building requirements. Experiment 1 replicates previous findings showing semantically light QNPs to be easier to process than contentful ones (Warren, 2003), and suggests that the quantifier *every* does not require contrast set building. Experiment 2 replicates the finding for *every*, contrasting it with a quantifier known to require contrasts (*only*), and provides information about negative quantifier use as well.

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1. Introduction

The study of quantification has a rich history in both formal linguistics and cognitive psychology. The formal linguistic work has tended to concentrate on the nature of quantifiers—i.e., what semantic type they are, as well as what structure they possess. Much of the work on quantifiers in psychology has been focused in a few areas: scope ambiguity and processing, quantification in formal reasoning, and the focusing properties of quantifiers due to polarity. One recently emerging psycholinguistic consideration of quantification has to do with how quantified NPs contribute to sentential complexity, and how resolving the meaning of a quantified NP is different from accessing the referent of, e.g., a definite description. In the pages that follow, some of the research done on quantification will be examined, and a discussion will be presented of two experiments which grew out of both the traditional quantificational studies as well as studies of referential processing and sentence comprehension.

Before we can begin to consider how quantifiers are processed, it is useful to discuss what they are. The layperson's definition of a quantifier is a word which expresses a contrast in amount. Quantifiers include words like *some*, *many*, and *every*, and are often found with an NP, though there are some quantifiers, such as *always*, which function as adverbs. Quantified NPs, (hereafter QNPs) unlike regular NPs, are non-referential—instead they propose relations between sets of individuals which are specified by the associated NP and predicate. Take the sentence "Every boy likes ice cream" for example. The noun *boy* picks out a set of boys, *likes ice cream* picks out a set of entities which like ice cream, and then the job of *every* is to relate those two sets of individuals. In this example, "boy" is called the restrictor of the quantifier and "likes ice cream" is the scope of the quantification. Quantifier, restrictor, and scope together make up the structure of the quantification. Because of this special non-referential status, linguists have described quantifiers and quantified expressions in a number of different ways.

1.1. Quantifiers in Linguistics

Quantifiers have been treated as various linguistic elements by different linguists. Jespersen (1933, and as cited in Aldridge, 1982:22) treated quantifiers in pre-modifying position as adjectives (c.f., sentences like in (1)).

1a). I ate delicious ice cream.
1b). I ate much ice cream.

It is not clear, however, under what conditions this view might hold true and which quantifiers it might affect, and so it will not be considered further. More useful is the idea that under certain conditions quantified expressions may be like indexical pronouns. For example, while the *every* in *every NP* is generally thought to be a determiner, Cushing (1982) has proposed that *everyone* functions like a pronoun. This view can be illustrated using the sentences in 2.

2a). A nurse wanted to go to the concert.
2b). Every nurse wanted to go to the concert.
2c). Everyone wanted to go to the concert.
2d). They wanted to go to the concert.

For 2a to be understood, the reader/listener must posit the discourse entity "a nurse." In 2b, for understanding, there has to be a *set* of nurses—i.e., in both 2a and 2b there is some semantic information about who the sentence is about, but in 2b the information is about a set, as opposed to an individual. This extra semantic information is not there in 2c—as long as you have a set of people, it is felicitous, regardless of what kind of people they are. For both 2b and 2c the context is consulted, but the set of people who can satisfactorily stand in for the quantified set are restricted more in 2b than in 2c. It is this restriction that comprises the difference between 2b and

2c. Finally, 2d gives only number information—it is clear there is more than one person, but nothing is known about them until context is considered, and the pronoun does not convey what proportion of the people in context they represent, unlike 2c. Comparing 2c and 2d, it seems that they share the property of providing something about either number (2d) or proportion (2c), but they both lack the restriction on the referent provided by 2a and 2b.

It is the similarity between 2c and 2d in specifying only number or quantity, and the difference in amount of restriction between 2c/d and 2a/b that are captured by calling words like *everyone* pronouns. The question is now what predictions the quantifier-as-pronoun idea might make if it was brought into the realm of sentence processing for sentences with quantifiers. It might predict that quantifiers like *everyone* would be processed like pronouns, which have been found to be easier to process than referring NPs (Warren & Gibson, 2002; Gordon, Hendrick, & Johnson, 2001).

Before considering the data on this issue it is useful to discuss another way that quantifiers have been described in linguistics, namely by focusing on the underlying relational structure of quantifiers. Quantifiers have been described as either "elements of logical structure" (McCawley, 1993:23), which suggests that they include more underlying structure than a referential NP, or functions (Heim & Kratzer, 1998). More specifically, the second description of the formal structure of quantifiers is that they are relational elements which have the semantic type of functions (e.g., Heim & Kratzer, 1998). The notion of semantic type comes from a set-theoretic, compositional version of semantics where words in a sentence combine to give a truth value for the entire sentence. Referential NPs are denoted as individuals (type <e>) while quantified NPs are sets of sets (type <<e, t>, t>). Each combines with a predicate (<e, t>) and returns a truth-value, t. Again, under this description, the structure posited for the QNP is more complex than that for the referential NP. Extrapolating directly from linguistic theory to processing, it seems reasonable to hypothesize that quantified NPs should always be more difficult than referential NPs because of the extra structure posited for them.

The available data from processing studies can help us evaluate the different descriptions of quantifiers put forth so far. The quantifier-as-pronoun view (which predicts QNPs which function like pronouns will be easier to process than referring NPs) and the quantifier-as-function theory (which predicts QNPs will *always* be more difficult to process than referring NPs) are the two candidates currently being considered. The available data favors the former, as it is not always the case that QNPs are more difficult than referential NPs. Warren & Gibson (2002) reported that in sentence positions of high complexity, participants found sentences containing certain quantified NPs to be easier than others with referential NPs in the same positions of high complexity. Those QNPs which were found to contribute to easier comprehension ratings were the same kinds of QNPs that were described as pronouns, above, e.g., words like *everybody* and *many people*. But what about other types of QNPs? Warren (2003, Experiment 2) found evidence that quantifiers with semantically contentful restrictors were more difficult to process than referring expressions, in a complex sentence frame. Together, the Warren & Gibson (2002) and Warren (2003) results suggest that the case of quantifiers is more complex than either of these linguistic descriptions, when exported directly into the sentence processing realm, would have predicted. It will now be useful to consider the work that has been done in psychology surrounding quantifiers to get a more complete picture of quantification. Included in the discussion are a consideration of scope ambiguity, use of quantifiers in formal reasoning, and focus effects due to quantifier polarity.

1.2. Quantifiers in Cognitive Psychology

When a sentence includes two quantifiers, scope ambiguities often result. Take, for example, the sentence “Every boy liked some girl.” In one reading of this sentence there is one specific girl such that every boy liked her. In this reading *some* has wide scope over *every*. In formal notation, the first reading is $\exists g\ [\forall x\ Bx \rightarrow Lgx]$, where g is a girl, and x is a boy, and the quantifier outside the brackets receives wide scope. In the second reading, *every* takes wide scope and the meaning that results is that every boy likes a girl, but the girls in question may be different. The second reading could be represented as: $\forall x[\ \exists g \wedge Lgx]$. Psycholinguistic inquiry into scope interaction has largely focused on which reading comprehenders prefer in ambiguous scope situations. Early studies (e.g., as discussed in Micham, Catlin, VanDerveer, & Loveland, 1980) found that people preferentially assigned wide scope to whichever quantifier came first in the sentence, making opposite choices for active and passive transforms of the same sentence. Later investigators found that the choice of quantifiers and predicates as well as the syntactic positions of each and the surrounding context must all be taken into account when predicting which reading a sentence with ambiguous scope relations will receive (Kurtzman & MacDonald, 1993; Villalta, 2003).

Another area of study in the psycholinguistics of quantification is how people do formal reasoning and problem solving with quantifiers. The type of problems typically given to participants are syllogistic—a type of logical puzzle using two quantifiers, such as: “All Xs are Ys. Some Ys are Zs. Are some Xs Zs?” Chater and Oaksford and colleagues (Chater & Oaksford, 1999; Oaksford, Roberts, & Chater, 2002) used syllogistic reasoning problems containing quantifiers to test what types of heuristics participants used when solving such problems. In their (2002) experiments they investigated how informative various quantifiers were for solving syllogisms by asking participants to rate which quantified sentence best described a scenario. For example, if given a setting like “In a room of 100 people, there are 50 artists of whom 15 are beekeepers,” the participant would have to rate sentences like “All of the artists are beekeepers” and “Some of the artists are beekeepers.” While their work was mostly focused on computing a scale of informativeness for various quantifiers based on how often people chose a quantifier, they also found that the pragmatics of quantification interacted with how people used the reasoning heuristics. More specifically, besides the amount conveyed by the quantifier, the crucial aspect contributing to how informative people viewed quantifiers to be seemed to be the polarity of the quantifier in question, as they rated positive and negative versions of *few* and *some* differently.

Quantifier polarity is another area related to quantification which has received considerable attention in the psycholinguistic literature. Polarity has to do both with whether the quantifier is negative, like *few*, or positive, like *a few*— and also with the focusing properties of quantifiers. Moxey and Sanford and their colleagues (e.g., Moxey & Sanford, 1987; Sanford, Moxey, & Paterson, 1994; Moxey, Sanford, & Dawydiak, 2001) have investigated this area deeply. The basic paradigm they used is continuation; adapting a typical linguistic test for focus effects which relies on the fact that only entities which are currently in focus can be referred to by pronouns (e.g., Chafe, 1972, as cited in Moxey & Sanford, 1987). Employing this principle, their typical experiments test the processing of anaphors referring back to quantified NP antecedents. The predicate of the second sentence ensured that the proper anaphoric binding occurred. An example of their materials would be: “Few kids ate ice cream. #They ate the vanilla ice cream first/ They said they’d rather eat the cake by itself.” In the first version, “they” improperly refers back to kids who ate ice cream, while in the second version, “they” refers to the focused set—those kids who did not eat ice cream. Moxey & Sanford (1987) found that positive quantity expressions focused the referent set of the QNP (e.g., in the sentence “A few kids ate ice cream” the kids who *did* eat ice cream are focused). Alternatively, negative quantity expressions focus the complement of the QNP (e.g., in “Few kids ate ice cream” the focused set is of those kids who *did not* eat ice cream). A later eye tracking study (Paterson, Sanford, Moxey, & Dawydiak, 1998) also found that the referent set must be inferred in sentences with negative quantifiers. Until recently, these studies have comprised a large part of the work on quantification. Accordingly, the literature does not contain many studies looking at the on-line, potentially incremental nature of quantifier processing, or dealing with active construction of quantifier meaning as opposed to understanding of final interpretations. It seems a likely extension, however, to wonder what interpretive processes are occurring at each step while the quantifier is being processed during reading. This question has begun to be investigated in the past few years.

1.3. Quantifiers in Psycholinguistics

One of the first sentence processing studies to compare the processing difficulty of quantified and referential NPs was Warren & Gibson (2002, Experiment 3). As mentioned above, in a study using complexity ratings, they found that the sentences containing quantified NPs were rated as easier than those with referential NPs in sentence positions of high complexity. The critical factor in this result was hypothesized to be the fact that the quantifier restrictors they used lacked any semantic content (e.g., *everyone*, c.f., *every doctor*).

Following up on that argument, Warren (2003) conducted a pair of self-paced reading experiments designed to test potential differences between referential and quantified NPs; manipulating the semantic content of the restrictor for the QNPs. Warren hypothesized that what she called semantically “light” QNPs (e.g. *everyone*) would be easier to process because resolving the restrictor set does not involve modifying a discourse model to include a new set, but rather simply accessing the default set of all relevant individuals already available in the discourse model. Semantically contentful QNPs like *every reporter,* on the other hand, require the reader to construct a new set of reporters. In her first experiment, the position of the quantified NP (matrix subject, embedded subject) was crossed with the content of its restrictor (light, contentful). The hypothesis that semantically contentful QNPs would be more difficult than light ones was supported for NPs at the embedded subject position, but not those at the matrix subject position. One possible reason hypothesized for this difference was that, since no context was provided, the matrix subject was considered the beginning of a new discourse, and therefore costs involved in integrating the set into the discourse did not apply.

Together, the results from Warren & Gibson (2002), and Warren (2003), Experiment 1, suggest that there is a difference between light and contentful quantified NPs. There are a number of potential reasons for this difference. The first such reason is the availability of an restrictor set—with light QNPs, accessing this set should be easier, as it is given by context, or there is a kind of default interpretation without context. Restrictor set availability was tested in Warren’s (2003) second experiment. Warren crossed the availability of a restrictor set in prior context with two quantifier types (*every* and *no*) and a definite description. The two quantifier types were included to see if the findings from the first experiment would generalize to a quantifier (*no*) which may vary in level of presuppositionality from *every*, a possibility which will be discussed in greater length below. The results of Warren’s second experiment suggest that having a restrictor set in context aids processing of both definite and quantified NPs, but the beneficial effects were smaller and not as long-lasting as the complexity difference between quantifier types. These findings support the idea that there may be other factors behind the difference between light and contentful quantified expressions.

Another possible contributing factor that was not tested in Warren (2003) has to do with contrast sets. This factor is the main one that will be considered in the current experiments reported below. To facilitate consideration of contrast sets it is first useful to offer a description of them. Certain linguistic expressions introduce to the discourse both the entities they refer to as well as a contrasting set of entities. For instance, in the sentence, "Only professors like beer" the contrast set is the contextually relevant individuals who aren't professors, and thus don't like beer. While it is sometimes necessary to compute this set, introducing a new referent introduces a cost (e.g., Murphy, 1984). The idea that there should be differences in the costs involved with various types of referents based on what must be constructed has been used in the referential theory of sentence processing (Altman & Steedman, 1988; Crain & Steedman, 1985). Originally used to explain how ambiguous alternative interpretations could be chosen between based on contextual information (c.f., syntax-first theories, e.g., Frazier, 1978), the principles the referential theory of sentence processing promotes have recently been tested with unambiguous sentences and found to play a role there as well (Grodner, Gibson, & Watson, in press). Furthermore, studies concerning the focus operator *only* (Sedivy, 2003; Ni, Crain, & Shankweiler, 1996) have shown that there is a computational burden involved in sentences including *only,* which requires a contrast set to be constructed. In an eye tracking study, Ni, Crain, & Shankweiler (1996) reported slower length-corrected first-pass reading times for regions with *only* as compared to the corresponding region in sentences with *the*. In a replication of that work, Sedivy (2003) found that sentences with *only* generated longer self-paced reading times at ambiguous areas of the sentence. Not every study looking for such effects has found them, however (e.g., Paterson, Liversedge, & Underwood, 1999).

While such contrast set-associated costs have been found with *only*, there are reasons to believe that they could be playing a part in the difference between *everyone* and *every x* as well. *Every X* can take a contrast set, especially when the restrictor is stressed (c.f., "Every PROFESSOR likes beer."). *Everyone*, though, does not allow contrast set building—*everyone* is all-inclusive for individuals relevant to the context, and there is thus no one left to be included in a contrast set. Consequently, if *every* + NP is found to require contrast set building, that finding would constitute a potential reason for the processing difficulty differences between *every* + NP and *everyone* as building more structure imposes costs (Altman & Steedman, 1988; Crain & Steedman, 1985).

1.4. Current Experiments

The current experiments grew out of the work discussed in the previous sections. The specific question addressed by the first experiment is whether the difference found in Warren (2003) between light and contentful quantifier restrictors is due to different requirements for construction of a contrast set. As discussed above, there are reasons to believe that *every NP* allows a contrast set. Experiment 1 tests whether having a contrast set in context aids processing for QNPs including *every*. If contrast sets are generally built when a reader encounters *every*, we expect that there will be slower reading times, corresponding to a greater processing cost for contentful QNPs than light QNPs, and that having a contrast set present in context will reduce reading times on contentful QNPs. The cost associated with computing the contrast set should only be present when there is a contentful restrictor.

The second experiment is designed to further shed light on the relationship between contrast sets and the complexity involved in processing quantifiers. Type of quantifier (every, only, no) is crossed with contrast set availability in the second experiment. As discussed above, *only* has been shown to exhibit contrast set effects in some other experiments, so a direct comparison will be made between *only* and *every*.

The *no* condition in Experiment 2 is included to begin to investigate negative quantifiers and negation more generally. Negation has long enjoyed a "special" status in cognitive psychology (e.g., Macdonald & Just, 1989; Just & Carpenter, 1971), and the focusing properties of *no*, a negative quantifier, should be different from those of the positive quantifier *every* (Moxey & Sanford, 1987). When considering Moxey & Sanford's (1987) findings discussed above, it seems it may be the case that *no* would show more sensitivity to contrast set presence than *every*, given that it focuses complement sets, which can be the same as contrast sets. An example will help illustrate the difference between the two kinds of sets. When considering a sentence such as "some students smoke," the referent set is students who smoke. The complement set is students who do not smoke. The contrast set can then be one of two things, based on which part of the proposition is contrasted. The contrast set in this example can either be students who do not smoke (the same as the complement set) or smokers who aren't students. Because of the fact that the complement set and contrast set are often the same set, and the fact that *no* focuses the complement set, *no* may be even more likely to require construction of the contrast set than *every*.

No also may show differences from *every* due to the fact that they vary in level of presuppositionality, i.e., in order to say "No puppies were going through the trash" there do not have to be any puppies in the current context. The same is not true for "Every puppy was going through the trash." On the other hand, *every* and *no* share at least one semantic property—both being universal quantifiers, they are downward monotonic in their first arguments, as can be seen in the sentences in 4).

The test for downward monotonicity, namely, that if a set has a property, all subsets of that set also have that property, fails for *only*, but succeeds for both *every* and *no* (assuming *bachelors* to be a subset of *men*):

4a). If no men wear pants, then no bachelors wear pants.
4b). If every man wears pants, then every bachelor wears pants.
4c). #If only men wear pants, then only bachelors wear pants.

What these examples in (4) show is that, while *every* and *no* pattern together here, showing downward monotonicity, *only* exhibits a different pattern. Because downward monotonicity has to do with set relations (more specifically, set/subset relations), in this case of the restrictor set, it is possible that the two quantifiers which share this semantic properties will show similar set manipulation (i.e., requirements for building, accessing, etc.) as far as contrast sets are concerned as well. While it is perhaps a rather weak argument for similarity between *every* and *no*, downward monotonicity has been considered a central property of negation, which is an important property for determining which set a quantifier will focus (Moxey, Sanford, & Dawydiak, 2001), and may thus play a role with these sentences as well. Experiment 2 will examine whether *no* patterns with *only*, as the contrast set/presuppositionality explanation would predict, or whether *no* patterns with *every*, as the downward monotonicity factor might suggest.

2. Experiment 1

Experiment 1 investigated the hypothesis that the complexity difference between light and contentful QNPs seen in Warren (2003) may have been due to the differential requirements involved in building contrast sets. If building a contrast set is contributing to the difference between light and contentful QNPs, data supporting the following predictions should be found:

having a contrast set in context should aid processing of contentful quantified expressions and make no difference with light quantified expressions, as the latter do not allow contrast sets to be built. These complexity differences should be seen on the QNP, as well as the verbs, as will be discussed below. A further aim of this experiment is to test the light/contentful distinction in the presence of a restrictor set. The second experiment from Warren (2003) suggested that building restrictor sets contributes to the processing complexity at an NP. If the light/contentful difference is still found when restrictor sets are present, the complexity differences found cannot only be the result of differential restrictor set availability.

In both experiments, the target sentences have subject-modifying object-extracted relative clauses, e.g., "The boy who everyone really liked ate pizza." If the complexity differences associated with different types of quantifiers are due to different requirements for accessing the restrictor set, effects should be seen on the QNP (*everyone* in the example). If, however, the differences are due to building the set of entities that fulfill the predicate, application of the quantifier relation, or contextual updating, effects would be expected on the embedded verb, as that is where those processes can occur. As set-building is likely going on in both places, we predict that complexity differences will be seen on both the QNP (and the following adverb due to spillover) as well as the embedded verb in Experiment 1. There may additionally be effects seen on the main verb that are predicted by the Dependency Locality Theory (DLT—Gibson, 1998; 2000), a theory which posits extra processing load at the end of syntactic dependencies (here at both verbs). The DLT will be discussed in more depth in the General Discussion.

2.1. Method

2.1.1. Participants

Forty native English-speaking undergraduates from the University of Pittsburgh participated in this moving window self-paced reading study. They fulfilled course requirements by participating. The study took around 30 – 35 minutes to complete.

2.1.2. Materials and Design

Experiment 1 crossed semantic content of the restrictor (light, contentful) with presence of a potential contrast set in context (present, absent). 32 items were constructed using these parameters and the quantifier *every*; examples are given below. In order to directly compare *everyone* and *every* NP in the presence of a restrictor set, all conditions include a restrictor set in context. In both versions, the first sentence introduces the sets. In the example stimulus set below, *shoppers* functions as the restrictor set. The potential contrast set, seen only in the first version, is *browsers*. The second sentence elaborates on the sets given by the first sentence, keeping the predications consistent regardless of contrast set presence. The third sentence then introduces the quantified expression, using a sentence frame that has been shown to increase complexity and thus is likely to produce effects if they exist (Warren & Gibson, 2002; Warren, 2003), namely, a subject-modifying object-extracted relative clause.

Contrast Set Present
In the bookstore there were browsers and shoppers.
The browsers wandered aimlessly and the shoppers filled their carts.
A cashier who everyone/every shopper completely trusted figured the totals.

Contrast Set Absent
In the bookstore there were many shoppers.
They wandered aimlessly and filled their carts.
A cashier who everyone/every shopper completely trusted figured the totals.

Along with the 32 experimental passages, subjects read 16 items from an unrelated experiment which were also complex and had two sentences of context but which used a different syntactic structure, and 40 filler passages of three sentences each written using varying syntactic structures. A yes/no comprehension question followed each passage. Order of versions was counterbalanced across subjects and order of items was randomized for each participant.

2.1.3. Procedure

Participants performed a moving window self-paced reading task[1]. After they received verbal instructions from the experimenter which were reiterated on the computer screen, participants were given practice with the task and reminded to try to read as naturally as possible. The experimental display consisted of dashed lines which indicated where the three sentences would appear. No sentence extended to two lines. The participant pushed the space bar on a standard keyboard to display the first unit of text. The next press of the space bar removed the displayed unit and presented the following unit. In order to facilitate presentation of this rather lengthy body of text passages, as well as prevent participants from developing a bar-pressing rhythm, text was displayed in a variety of different-sized units, including word-by-word, phrase-by-phrase, and in some cases, an entire sentence. The critical regions of the experimental items were always shown in word-by-word format to facilitate the recording of processing time on individual words. The filler items were displayed in such a manner as to obscure this pattern. As participants worked their way through the sentences, the time between key presses was recorded. After each passage, a yes/no comprehension question was asked. Participants received feedback

[1] Stimuli were presented on a PC running experimental software designed by Doug Rohde (Linger 2.85).

on incorrect trials only, and were told at the beginning to take this feedback as an indication they should read more carefully.

2.2. Results

All subjects had question answering accuracy rates of greater than 71% on the experimental items, and 78% overall. All 40 subjects are thus included in the following analyses. Table 1 presents comprehension question accuracies by condition for Experiment 1.

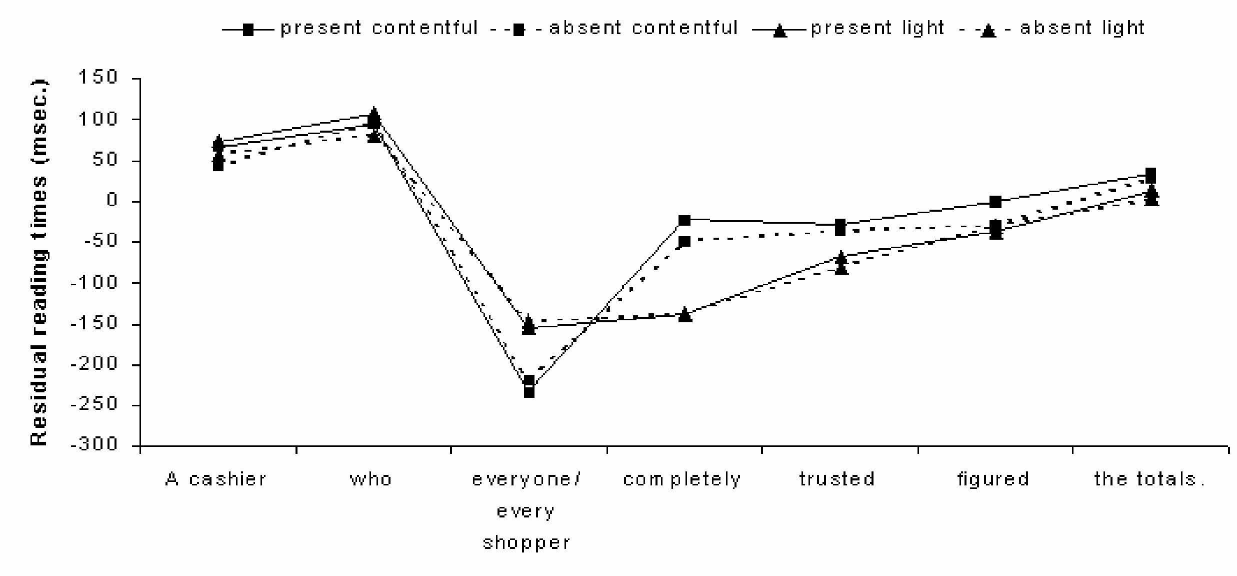
Table 1. Percentage of comprehension questions answered correctly by condition, Experiment 1

Condition	Percentage correct
Present, light	91
Present, contentful	88
Absent, light	92
Absent, contentful	90

2x2 repeated measures ANOVAs were run on the comprehension question data, with both subjects (F1) and items (F2) as random factors. No reliable differences were found for accuracy, although restrictor weight showed a trend toward significance such that the light conditions were easier, as predicted based on Warren, 2003 ($F1\ (1, 39) = 3.2$, $MSe= 103.5$, $p = 0.08$; $F2(1,31) = 3.8$, $MSe = 66.02$, $p = 0.06$). All other Fs were < 1.1, with ps of > 0.31.

Regions used for presentation and analysis were as follows: Region 1 contained the quantified NP. Region 2 was the following adverb. Region 3 contained the embedded verb, and Region 4 was the main verb. Word length corrections were done using a regression equation which predicts RTs from word length for each participant using all experimental and filler items (Ferreira & Clifton, 1986; Trueswell, Tanenhaus, & Garnsey, 1994). Times were trimmed at +/-3 SDs from the mean in each region in every condition, resulting in a loss of less than 0.07% of the data. Figure 1 presents the reading times for the sentences.

Figure 1. Mean length-corrected reading times for Experiment 1.



Reading time results will be discussed by factor rather than by region. The first factor of interest was quantifier restrictor weight. Based on Warren (2003), we expected to find that quantified expressions with light restrictors would be read faster. On the quantified NP, however, there was a reversal of the predicted weight effect, such that contentful quantified expressions were read an average of 75 ms faster than light quantified expressions ($F1(1, 39) = 54.8$, $MSe = 3906.4$, $p < 0.00$; $F2(1,31) = 38.223$, $MSe = 4521.4$, $p < 0.00$). It seems likely that this effect on the QNP is due to lexical repetition priming, though, because these are the cases where the participant has seen the restrictor twice before. This view is further supported by the fact that in the other critical regions, the expected pattern of weight effects is found, such that light quantified expressions were read faster. The pattern of light QNPs being faster was reliable on the adverb and the embedded verb (adverb: $F1(1,39) = 89.8$, $MSe = 4733.2$, $p < 0.00$; $F2(1, 31) = 106.9$, $MSe =3145.9$, $p < 0.00$; verb: $F1(1, 39) = 26. 9$, $MSe = 2509.7$, $p < 0.00$; $F2(1,31) = 50.0$, $MSe = 1094.8$, $p < 0.00$). The main verb also showed this effect of weight ($F1(1,39) = 3.7$, $MSe = 14940.2$, $p = 0.06$; $F2(1,31) = 5.8$, $MSe = 2226.9$, $p = 0.02$). Together these results suggest a strong influence of weight such that quantified expressions with contentful restrictors cause more processing difficulty on the adverb and the embedded and main verbs.

Contrast set presence was the second factor manipulated in this experiment. We had predicted that having a contrast set present in context would aid processing of the contentful quantified NPs, but this prediction was not borne out by the data. While there were a few significant or marginal effects of contrast set presence, they contradict each other and do not hold for both analyses, which suggests that there is little overall effect of having a contrast set present. A significant effect was found in the items analysis such that the quantified NP (Region 1) was read an average of 18 msec faster when the contrast set was present ($F1(1, 39) = 2.8$, $MSe = 11606.9$, $p = 0.10$; $F2(1,31) = 5.6$, $MSe = 1705.2$, $p = 0.02$). On the adverb (Region 2), however, there was a trend towards a reversal of this pattern ($F1(1,39) = 3.3$, $MSe = 3404.1$, $p = 0.08$; $F2(1,31) = 4.0$, $MSe = 1705.2$, $p = 0.05$). There were no other significant effects of contrast set in any other region (all $Fs < 2.8$, all $ps > 0.1$). Overall, the results for contrast set presence suggest that there is no consistent and meaningful effect.

One final interesting result was the presence of an interaction in Region 4 (the main verb). This interaction appears to be driven by the contentful condition being affected by the contrast set presence while the light condition is unaffected. This finding supports the hypothesis that light QNPs do not require contrast set building. The interaction in this region was significant in both analyses; $F1(1, 39) = 5.8$, $MSe = 2389.8$, $p = 0.02$; $F2(1,31) = 6.86$, $MSe = 1766.4$, $p = 0.01$. No other region showed a significant interaction (all $Fs < 2.6$, all $ps > 0.1$). Possible reasons for the interaction being restricted to Region 4 will be discussed below.

2.3. Discussion

In this experiment, the factors of quantifier restrictor weight and contrast set presence were manipulated. The results reconfirmed the processing difficulty differences for quantifiers with restrictors of different semantic weights found in Warren (2003), again showing that quantified NPs with light restrictors are read more quickly than those with contentful restrictors. More importantly, because the presence of a restrictor set was kept constant in all conditions, these results suggest that the processing difference Warren found from manipulating semantic weight was not only due to difficulty resulting from the process of establishing restrictor sets in a discourse model. The complexity effects were predicted to be found on all four critical regions due to restrictor set building (the QNP), spillover (the adverb), predicate set building/dependency resolution (the embedded verb) and dependency resolution (the main verb). Although the QNP (Region 1) did not show the predicted weight effects, the reversal in this region is likely due to lexical repetition priming, given that the fast conditions are those presenting words the subject has seen before. The other three regions all showed significant complexity differences in the predicted direction.

The interaction found in Region 4 (the main verb) between contrast set presence and weight provides support for the idea that light QNPs do not allow contrast set building. When considering what the reader has to do around the region containing the main verb, it is not surprising that the interaction is seen in this general area. At the embedded verb, the region just prior to where the interaction was found, the reader could potentially be building a set of people who fulfill the predicate, updating his or her discourse context, and/or applying the relationship specified by the quantifier. Additionally, the verbs are locations where syntactic dependencies between the verbs and their arguments must be established. Many theories (e.g., Gibson, 1998; 2000) hypothesize that constructing these dependencies causes processing difficulty on the verbs, because the verbs in object-extracted sentences like those tested in the current experiment often are locations of extreme processing difficulty (e.g., Gibson, 1998; King & Just, 1991). It still remains to be explained why the interaction was not seen on the embedded verb, however. One potential explanation is that because the task was self-paced reading, it is possible that the effect is delayed until the main verb due to an artifact of a button pressing rhythm (i.e., the subjects may have pressed the button to remove the embedded verb before processing it). Although we used a variable window of presentation specifically to avoid such a rhythm, all target sentences (written in a unique sentence frame) were mostly word-by-word, and possibly became predictable.

Finally, given that no consistent effects of contrast set were found, the results further suggest that, although *every* can elicit contrast set building when given proper stress[2], contrast set building is not obligatory, and as such *every* is not consistently sensitive to the presence or absence of a contrast set in preceding context. In order to more thoroughly confirm this hypothesis, however, it should be verified that the contrast set manipulation was adequate to find an effect if there was one. This verification is one of the goals of Experiment 2. The other aim addressed by Experiment 2 is to further investigate the status of negation in these situations.

3. Experiment 2

Experiment 1 was designed to test whether potential contrast set effects could be responsible for part of the difference found between light and contentful versions of quantified expressions in Warren (2003). The predicted effects were not found, however, suggesting a need for further investigation to ensure that the manipulation worked and that the null effects found reflect the correct state of affairs. Experiment 2 was designed for this purpose. In order to

[2] Possibly *only* when given proper stress.

validate the contrast set manipulation, a replication of Experiment 1 was done which included conditions with the focus operator *only*. As discussed above, *only* has been shown to be sensitive to contrast set effects in some studies (Sedivy, 2003; Ni, Crain, & Shankweiler, 1996), and so may also demonstrate this sensitivity in the current experiment if the manipulation of contrast sets was valid. More specifically, it was expected that when a contrast set was present in context, *only* sentences would show less processing difficulty on the QNP as the reader will have already constructed the contrast set and will not be doing so at the restrictor. It is also expected that the processing difficulty differences may be seen on the regions after the QNP as well, for the reasons discussed above. If a difference in the *only* conditions is found such that having a contrast set in context leads to less processing difficulty on the QNP, it will verify that the contrast set manipulation used in Experiment 1 was valid, and will strengthen the suggestion that *every* is not sensitive to contrast set manipulation. Experiment 2 was also designed to directly replicate the latter claim, as conditions with *every* were also included.

Another goal of Experiment 2 was to further examine *no*, which differed from *every* in Warren's (2003) second experiment by causing embedded clauses in which it appeared to be read more slowly. As discussed above, the case of *no* is rather complex—it shares the semantic property of imposing downward monotonicity on its first argument with *every*, but in regards to focus effects it should be more like *only*, as it is negative in polarity, and thus may focus the complement set (Moxey & Sanford, 1987). The set-building properties of *no* may be different simply because of its meaning as well. Consider the sentence “No undergraduates really like homework.” Unlike the same sentence with *every* or *only*, with *no* a set of undergraduates may not be required to be in the context. When processing the example sentence with *no*, it is possible the reader constructs a set of undergraduates on the noun regardless of the fact no one in it fulfills the predicate, but then it is unclear whether the reader would construct the predicate set on the predicate, or instead make a contrast with the adverb, in which case she or he may still wait until the predicate to build the adverb-contrasting set. This uncertainty about what *no* will require in terms of set building will be partially addressed by the current experiment, which was also designed to investigate whether *no* patterns more like *every* or *only*. Given that the argument for downward monotonicity is weaker than the argument for focus, it was expected that, similar to *only*, *no* would show contrast set effects such that having a contrast set in context would result in faster reading times for the quantifier.

3.1. Method

3.1.1. Participants

Forty-two native English-speaking undergraduates from the University of Pittsburgh Psychology Department Subject Pool participated in this study. They fulfilled course requirements by participating. The study took around 30 – 35 minutes to complete.

3.1.2. Materials and Design

Experiment 2's 2x3 design crossed quantificational determiner (every, only, no) with presence of a potential contrast set in context (present, absent). 36 items were constructed using these parameters; examples are given below. As in the first experiment, the first sentence always includes a restrictor set and (for *present* conditions only), a potential contrast set; the second sentence elaborates the sets, and the third sentence presents the quantified expression in a subject-modifying object-extracted relative clause frame, which has been shown to be very difficult to process (e.g., Warren & Gibson, 2002; Warren, 2003).

Contrast Set Present
At a meeting of the art club there were painters and models.
The painters squinted at their canvases and the models sat on stools.
A teacher who every/only/no painter(s) intently watched critiqued the pictures.

Contrast Set Absent
At a meeting of the art club there were many painters.
The painters squinted at their canvases and sat on stools.
A teacher who every/only/no painter(s) intently watched critiqued the pictures.

Along with the 36 experimental passages, subjects read 56 filler passages of three sentences written using varying syntactic structures and different levels of complexity. A yes/no comprehension question followed each passage. Order of versions was counterbalanced across subjects and order of items was randomized for each participant.

3.1.3. Procedure

Experiment 2's procedure was identical to Experiment 1's.

3.2. Results

All subjects had question answering accuracy rates of greater than 75% on the experimental items, and 77% overall. All 42 subjects are thus included in the following analyses. One item had an accuracy of only 54% and so was excluded from accuracy analyses. All other items had accuracy scores of greater than 69%. Table 2 presents comprehension question accuracies by condition for Experiment 2.

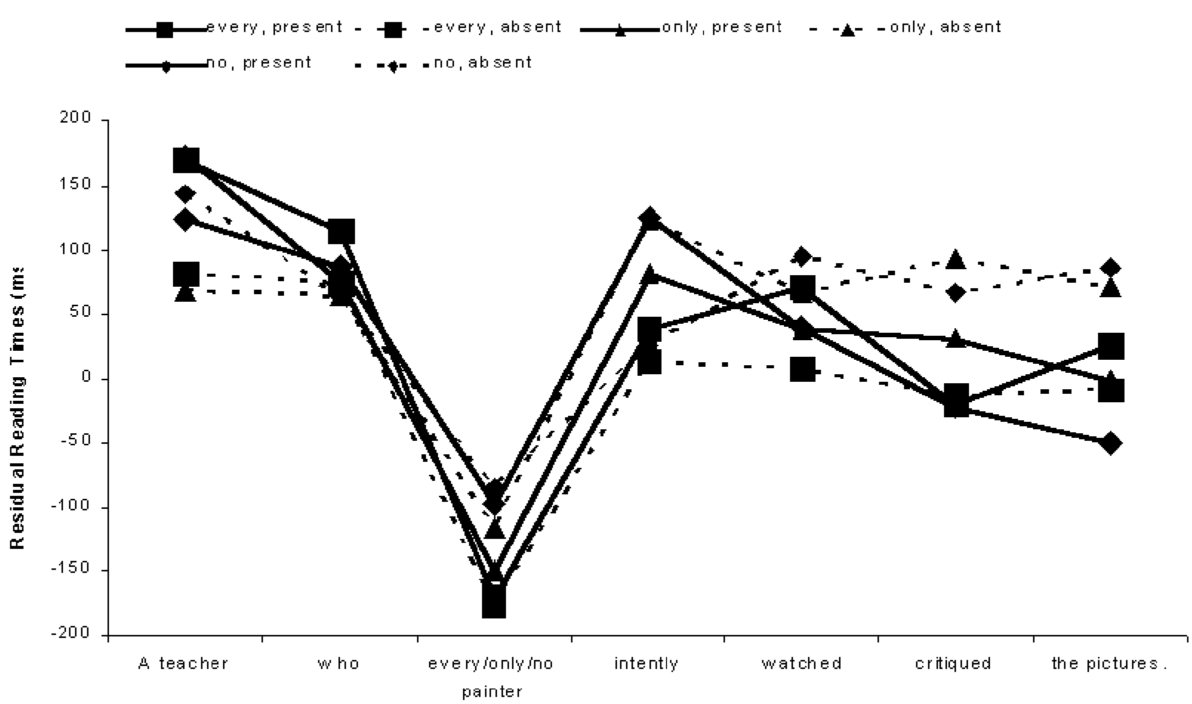
Table 2. Percentage of comprehension questions answered correctly by condition, Experiment 2.

Condition	Percentage correct
Every, present	89
Every, absent	86
Only, present	87
Only, absent	90
No, present	88
No, absent	89

2x3 repeated measures ANOVAs were run on the comprehension question data, with both subjects (F1) and items (F2) as random factors. No reliable differences were found in the accuracy data—all Fs < 1.3, and all ps > 0.27.

Regions of analysis were as in Experiment 1—Region 1 is the QNP, Region 2 is the following adverb, Region 3 is the embedded verb, and Region 4 is the main verb. As in the first experiment, word length corrections were done (Ferreira & Clifton, 1986; Trueswell, et al., 1994) and repeated measures ANOVAs were computed on the length-corrected reading time data, using both subjects (F1) and items (F2) as random factors. Times were trimmed at +/-3 SDs from the mean in each region in every condition, resulting in a loss of less than 0.02% of the data. Figure 2 presents the reading times for the sentences.

Figure 2. Average length-corrected reading times in msec for each sentence position, Experiment 2.

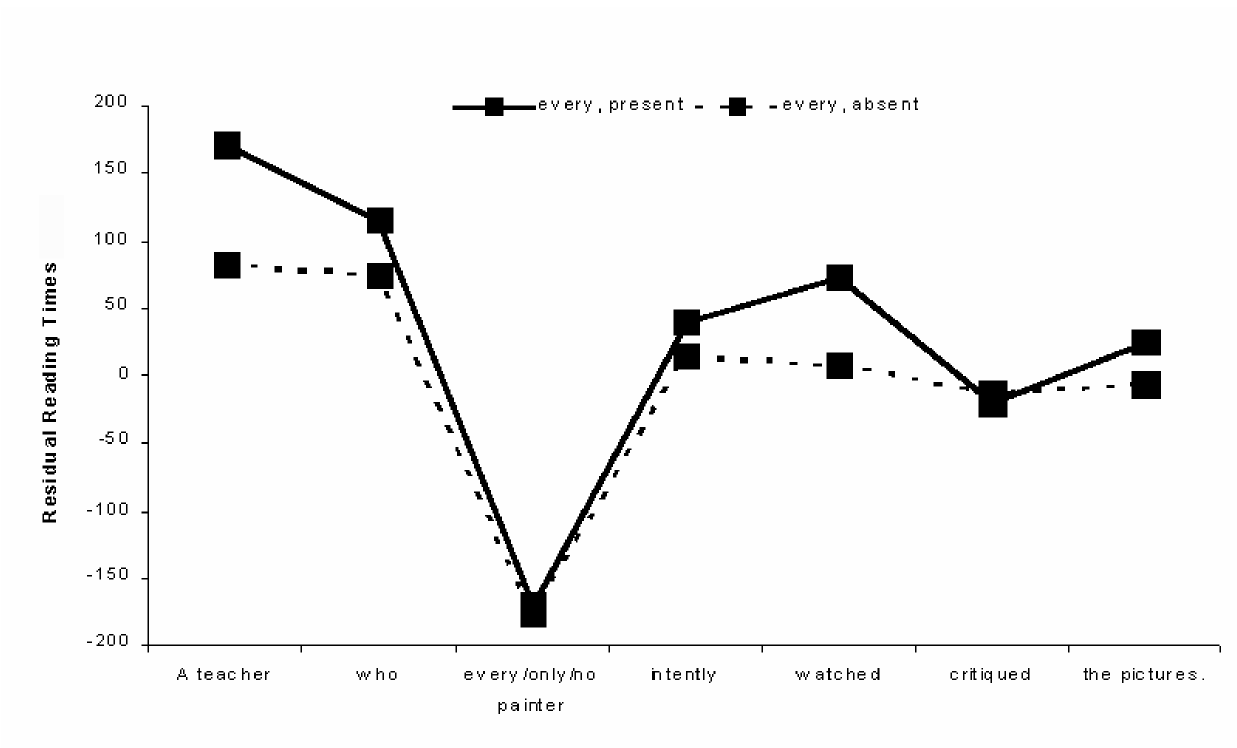


Results will be discussed by factor. It was hypothesized that having a contrast set present in context would decrease reading times for all quantifiers which required contrast set building, due to the fact that it would require readers to build the contrast set before the target sentence. Based on Experiment 1, *every* was not expected to show this benefit, but *only* was, because of the work by Sedivy (2003) and Ni, Crain, & Shankweiler (1996) discussed above. The main verb (Region 4) was the only region to even approach showing a main effect of contrast set presence, ($F1(1, 41) = 2.7$, $MSe = 18027.3$, $p = 0.11$; $F2(1, 34) = 2.1$, $MSe = 17511.6$, $p = 0.16$). All other Fs were less than 0.9, $ps > 0.35$. The difference is in the expected direction, with the *present* conditions being about 20 ms faster than the *absent* conditions overall. However, the results from any overall test may be misleading because the different quantifiers varied in their requirements for a contrast set.

The second factor manipulated in this experiment was the quantifier used. It was expected that *only* would benefit from the presence of a contrast set in context, that *every* would not, and that *no* might behave more like *only*, for the reasons discussed above. The differences between these quantifiers can be seen in the graph, and repeated measures ANOVAs yield a main effect of quantifier that are significant in all four regions, (QNP: ($F1(1, 82) = 14.2$, $MSe = 224351.9$, $p < 0.0001$; $F2(1, 68) = 11.4$, $MSe = 175228.6$, $p = 0.0001$), adverb:($F1 (1, 82) = 6.9$, $MSe = 117624.6$, $p = 0.0017$; $F2(1, 68) = 6.7$, $MSe = 90642.2$, $p = 0.002$), embedded verb ($F1 (1, 82) = 3.6$, $MSe = 45535.4$, $p = 0.03$; $F2 (1, 68) = 4.1$, $MSe = 48719.5$, $p = 0.02$), and main verb: ($F1 (1,82) = 5.8$, $MSe = 53159.4$, $p = 0.004$; $F2(1,68) = 4.9$, $MSe = 40947.0$, $p = 0.01$)). The difference is driven by the fact that, when averaging over all four regions, the *no* and *only* conditions are about 45 ms slower than the *every* condition, for trials where the contrast set is absent, while the *no* and *only* conditions are about 15-20 ms faster than *every* when the contrast set is present. While there is no significant interaction, there are these numerical trends in opposite directions. These results support the hypothesis that these quantifiers have different requirements for discourse structure building.

The overall ANOVA effects do not tell the whole story, however, as the different quantifiers tend to show dissimilar patterns, it is useful to consider each quantifier in turn. The first quantifier to be considered is *every*. Experiment 1 suggested that *every* was not sensitive to the presence of potential contrast sets in context. What those results suggest is that *every* does not require the reader to access a contrast set. These findings were reconfirmed by Experiment 2. Instead of the pattern that would be expected from a quantifier requiring contrast set building, *every* actually showed a reversal—having a contrast set present in context was either slightly damaging or made no difference (depending on the region). Figure 3 provides a graphic representation of these observations.

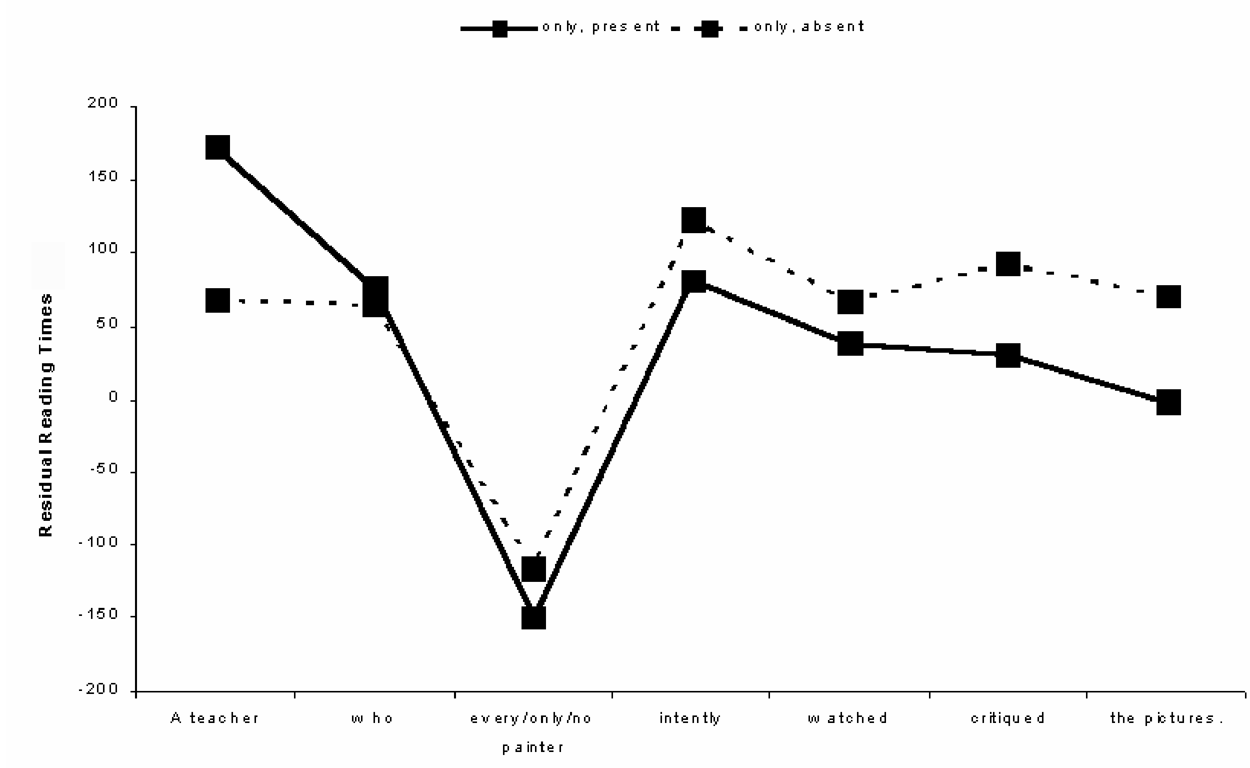
Figure 3. Reading times (in ms) for conditions using *every* in Experiment 2.



Averaged across all four critical regions, the overall mean for the *every, present* condition was about 25 ms slower than the mean for the *every, absent* condition. T-tests by subjects and items showed that these means were not reliably different (t1(334) = 1.09. p = 0.14 ; t2(285) =1.13, p = 0.13), and all single-region contrasts were found to be not significant as well, suggesting that having a contrast set in context or not does not make a difference for sentences with *every*.

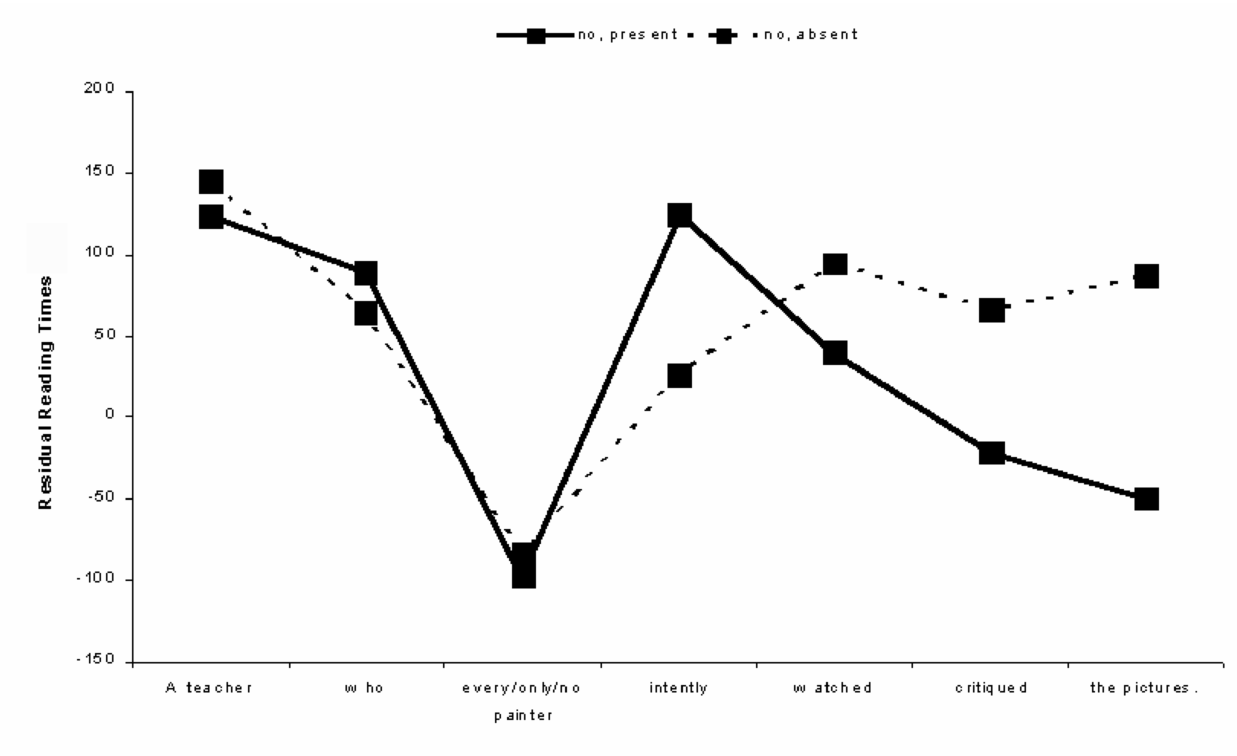
The next quantifier used was *only*. Because *only* has shown contrast set-related effects in other experiments, as discussed above, it was expected to show such effects in the current experiment as well. The specific prediction we expected to be borne out by the data is that having a contrast set in context would be beneficial in conditions with *only*, resulting in faster reading times for those conditions. This hypothesized state of affairs was observed, as the *only, present* condition was found to be marginally faster than the *only, absent* condition, when averaged over all four critical regions, (t1(334) = -1.39, p = 0.08; t2(284) = -1.44, p = 0.08), although single-region contrasts were not significant. These results are generally in line with the other experiments showing contrast set effects with *only*, and they additionally provide some weak evidence that the contrast set manipulation we are using is valid, suggesting that the null findings obtained for *every* in Experiment 1 are not due to a faulty manipulation. The difference between the case of *only* and the case of *every* can be seen by comparing Figure 3 to Figure 4—note that in the latter, the positions of the lines are reversed. A t-test comparing difference scores for *every* and *only* (present condition – absent condition for each) confirmed that these conditions differed significantly, (t1(334) = 2.37, p = 0.009; t2(284) = 2.25, p = 0.01).

Figure 4. Reading times (in ms) for conditions using *only* in Experiment 2.



The final quantifier used in this experiment was *no*. It was not entirely clear at the outset what would happen with *no*. On one hand, *no*, like *every*, is downward monotonic and follows similar set/subset relations and so might be expected to pattern with *every* when contrast sets are at issue. Alternatively, because *no* differs from *every* in level of presuppositionality and polarity, *no* might be expected to pattern differently. One final possibility is that *no* will exhibit a pattern which differs somewhat from both *only* and *every*. Negation has long been granted a special status in psychology (e.g., MacDonald & Just, 1989; Just & Carpenter, 1971), and in the experimental sentences, negation could operate at either of two levels, perhaps complicating matters. With *no* in the position it is in our target sentences (e.g., A teacher who every/only/no painter(s) intently watched critiqued the pictures.), it could be taken as providing either adverbial (e.g., no one watched *intently*, but some watched *lazily*) or sentential (no one watched at all) negation. Because of these complicating factors, *no* conditions may yield different results from the other conditions. The results were closest to the last of these possibilities. For the most part, *no* showed a similar pattern to *only*. Because of the reversal on the adverb, t-tests over all regions comparing *no* to other conditions were nonsignificant, but Figure 5 confirms that *no* tends to pattern like *only*.

Figure 5. Reading times (in ms) for conditions using *no* in Experiment 2.



Together these results suggest that *no*, like *only*, may require contrast set building, while *every* does not. The results can be seen graphically in Figure 5, which shows a similar pattern to Figure 4. The story is, however, slightly more complex with *no* than with *only* as there is a reversal of the pattern on the adverb (Region 2), perhaps due to a scope ambiguity *no* introduces (see General Discussion for more consideration of this hypothesis). What these results suggest is that, although contrast set building does contribute to the complexity of *no*, there may be such other factors as scope ambiguity at work as well.

3.3. Discussion

Experiment 2 investigated how three different quantifiers (*every*, *only*, and *no*) are processed when there is a contrast set in context. One of the main objectives of this experiment was to verify that the sentence frame used in Experiment 1 would be sensitive to contrast set effects if they did exist. In order to do this, a quantifier which was known to be sensitive to contrast set information (*only*) was compared to *every*, which was found in Experiment 1 to not be sensitive to the presence of a contrast set in context. The results of Experiment 2 suggested that our manipulation worked, because *only* showed the expected effects of benefiting from having a contrast set in context. As *every* still did not show these effects, Experiments 1 and 2 together provide good evidence that *every* does not require contrast set building. *No* exhibited a pattern much like *only*, although there were some differences, to be discussed below. None of the effects found, however, were statistically significant in an individual region. Only the means across the entire sentence differed significantly from each other. This pattern is in direct contrast to the first experiment as well as the experiments in Warren (2003), in which complexity effects were found to occur on specific points in the same sentence frame used here. It could be that there are time-locked effects in the current experiment but that they are too small at any specific point, and thus only significant when averaging across regions, or it could be that processing differences resulting from a weight manipulation are simply more robust than processing differences based on the manipulation of different quantifiers. It is an open question which of these explanations is more accurate.

4. General Discussion

In the sections above, the results of two experiments which dealt with discourse set building and the processing of quantified expressions in sentences were reported. The first experiment looked at whether a difference in processing between a quantified NP with a semantically light restrictor and that same quantifier with a semantically contentful restrictor was due to differential requirements for building contrast sets. Although complexity differences varied with the semantic weight of the QNP's restrictor, replicating Warren (2003), no consistent effects of contrast sets were seen. This latter result suggests that *every* does not require contrast set building. The second experiment compared the quantifier from Experiment 1 to two other quantifiers, one of which was known to require contrast set building (*only)*, and one for which the contrast set requirements were unclear (*no*). The fact that *every* does not require contrast set building was replicated in this experiment and was compared with the contrast set building effects seen with *only* and *no*. These experiments not only provide evidence about processing of the three specific quantifiers used, but the results of these experiments also speak to a number of larger issues including the questions of whether building a set in a discourse model imposes a processing cost and what kind of cost it is, whether having built a set then impairs later understanding and integration of the following parts of the sentence, and finally what the architecture of the system responsible for sentence processing is like. The evidence relevant to each question will be considered in turn.

First, there are a number of results which shed some light on online quantifier processing in general as well as show differences between types of quantifiers and what they require the listener to do so that they can be interpreted. When readers are faced with a sentence that includes a quantifier, they have several tasks to do in order to understand that sentence. When they first read the quantified NP, they can be accessing the set of people it contains, but they cannot finish the quantification as they do not yet have the predicate. Upon reading the predicate, the reader can then access the set of people who fit the predicate, and apply the quantifier relation. For example, when reading "Every boy likes puppies," after *boy* the reader can have a set of relevant boys in mind, but does not know what he or she will be told about those boys. Only upon reaching *likes puppies* can the reader then access the set of puppy-likers, and use the quantifier given to relate the two sets together. Where the complexity with quantifiers is found can thus help us understand which operations involved in processing quantifiers (i.e., building contrast or predicate sets, and/or applying the quantification relation) cause increases in processing cost. Seeing increased reading times only on the QNP would suggest that it is building/accessing the set of boys that is problematic. This was the result obtained by Warren (2003). Seeing increased reading times on the verb associated with the QNP (here, our embedded verb) would suggest that the complexity is caused by some form of contextual updating, accessing the set of puppy-likers, or possibly application of the quantifier.

The current experiments provide some evidence for complexity at both sentence positions. In Experiment 1, complexity effects due to the weight manipulation are seen on the word following the QNP region (a reversal is seen on the QNP region itself which is likely due to lexical priming) and the embedded verb both. In Experiment 2, for the quantifier which shows complexity differences (albeit weak ones) due to contrast set building (*only*), these differences are again seen as trends not only at the QNP, but also throughout the rest of the sentence, including on the embedded verb. The results from these experiments suggest either that there is an added processing cost associated with both parts of the quantification (i.e., accessing the restrictor set and then either doing the quantification over the predicate or computing the nuclear scope) or that having built a set on the QNP slows you down later in the sentence as well. These results are in conflict with the results reported in Warren (2003), which showed complexity effects only on the QNP and the following adverb. One possible reason for this discrepancy has to do with potential subject pool differences between the two studies. In studies Warren has conducted since, using the same subject pool as the current studies, different patterns of response have been found (T. Warren, personal communication, November 4, 2004). Overall, the evidence seems to lean toward the idea that in order to process a sentence with a quantifier in it, one needs to compute at least a referent set as well as a relationship between that set and the predicate, and thus there will likely be complexity effects seen both on the QNP and on the embedded verb in complex structures.

While there seems to be a general processing scheme for quantified expressions, it should be noted that not all quantified expressions are created equal. Previous studies (Warren & Gibson, 2002; Warren, 2003) found evidence that quantified expressions were not processed in the same manner as referential expressions—some QNPs (i.e., those with semantically light restrictors) were found to be easier than referential NPs (Warren & Gibson, 2002), while semantically contentful QNPs were found to be more difficult than referential NPs (Warren, 2003). These processing differences based on weight were replicated in Experiment 1, where the semantically light condition exhibited faster reading times than those from the contentful condition. Potential explanations tested have included the idea that, while light ones do not require set-building, contentful quantified expressions require the building of restrictor sets (Warren, 2003) or contrast sets (the current experiments), but neither has been conclusively shown to be responsible for the full effect, although building restrictor sets seems to make some difference (Warren, 2003). One possible further explanation for the complexity differences seen based on weight that remains untested was suggested by the literature reviewed above—i.e., contentful QNPs might simply require different processing than light ones.

As discussed in the introduction, certain quantifiers have been described by linguists as pronominal. It seems that light quantified expressions could be classified among those quantifiers which act like pronouns. Both pronouns and light quantified expressions have been found to be easier to process than other expressions. Pronouns were investigated by both Warren & Gibson (2002) as well as Gordon, Hendrick, & Johnson (2001), among others. Warren & Gibson (2002) compared complexity ratings for doubly-embedded sentences with various types of NPs in the centermost position. They found those with pronouns in them to be rated as less complex than other types of NPs. Gordon et al., (2001) looked at reading times and accuracy for pronouns and definite descriptions in object- and subject-relative sentences. They found that including a pronoun, as opposed to a definite description, would reduce the commonly-found greater complexity for object-relatives. Both studies found indexical pronouns to reduce complexity in some form, and Warren & Gibson (2002) additionally mention that a possible reason for this reduced complexity is that indexical pronouns are default, i.e., given in the discourse context. This argument also can be used to make a case for a light-quantifier-as-pronoun view, in that indexical pronouns (i.e., *you* and *I*) are commonly held to be default—"given" in the discourse, because every discourse has a speaker and a listener. Perhaps *everyone* is similarly available as a default discourse element. Whether this is a property unique to *everyone* because of its universal status or is common to other light quantified expressions is a matter for future research, and will be discussed in more detail below.

All three of the quantifiers used in the current experiments were also shown to have unique properties. First, including *only* in Experiment 2 not only provided a way to validate the contrast set manipulation worked, it also allowed some time course evidence to be gathered about *only*. While previous studies concentrated more on focus and ambiguity resolution (Sedivy, 2003; Ni, Crain, & Shankweiler, 1996), this experiment provided some evidence that *only* requires a contrast to be made, as evidenced by shorter reading times when a contrast set was provided in context than when it had to be computed at the QNP. Furthermore, the results suggest that in relative clause sentences at least, the effects of making this contrast for *only* can be seen as trends beginning on the QNP and lasting throughout the sentence. Although these findings are weak, they are somewhat contrary to findings which suggest that the effects of focus are not found until after a delay. For example, Almor & Eimas (2000) report four studies using focus produced by clefting and cross-modal lexical decision which suggest that focus effects do not come into play until at least a second after the word in question is presented. The weakness of our results for *only* perhaps reflects that contrast effects are difficult to obtain, a view supported by the existence of studies which do not find such effects (e.g., Paterson, Lieversedge, & Underwood, 1999). The *only* condition in our Experiment 2 also provided a nice contrast to the *every* condition, where there were no effects of contrast set presence seen—a finding which suggests that *every* does not require contrast set building. The *no* condition, however, was a bit more complicated.

Originally, it was unclear whether *no* would exhibit a pattern similar to *every* because they both exhibit the tendency of being downward monotonic to some degree (a property Moxey, Sanford, and Dawydiak (2001:439) consider fundamental to these quantifiers), or whether *no* would pattern like *only* because they both focus the complement set, which can be the same thing as the contrast set. As discussed above, contrasts can be made with either the restrictor set or the set of people who fulfill the predicate (for example, in the sentence “No kids like broccoli” contrasts could be made with either *kids*, or *liking broccoli*). Because of the reported tendency for quantifiers like *no* to focus the complement set, it can be hypothesized that at least part of the time *no* would be focusing the set that is also the contrast set—thus exhibiting a property which is like that seen with *only*.

As it turned out, the data from *no* look similar to the data from *only,* suggesting that focus is more important than downward monotonicity for predicting how different quantifiers will behave in the presence of contrast sets. Both *only* and *no* seem to require contrast set building, and show benefits if the contrast set is built before the contrast must be made (i.e., on the quantified NP). The fact that *no* shows the pattern to a lesser extent is consistent with at least two possible explanations. First, the fact that the contrast set is not always the same as the complement set, which *no* is thought to focus (Moxey & Sanford, 1987; Moxey, Sanford, & Dawydiak, 2001) may be playing a role. More specifically, if what *no* is focusing is only sometimes the contrast set, the effects seen for the factor of contrast set presence may not be as strong as *only* because they are only happening on some trials. An example (5, below) will help illustrate this point. In 5a-b, it can be seen that *only* can just make a contrast with the restrictor set, but not the set of people who fulfill the predicate, whereas 5c-d show that *no* can contrast either one.

5a). Only students went to the store. Teachers didn't go.
5b). Only students went to the store. #They went to the fair instead.
5c). No students went to the store. Teachers went instead.
5d). No students went to the store. They went to the fair instead.

Future research could investigate the conditions wherein *no* sentences provide a natural contrast with the complement set or the other possible contrast set. For example, under what conditions does a sentence like "No professor likes beer," suggest a contrast with professors as opposed to a contrast with liking beer? It is possible, too, that while *no* is thought to focus the complement set, a more accurate description is that it focuses a contrast set, whichever one is relevant. So far, Moxey and Sanford's (1987, Moxey, Sanford, & Dawydiak, 2001) data could not decide between these alternatives as they do not address contrast sets and do not explicitly test *no*, only other negative quantifiers. Investigating the focus pattern of *no* could be very informative to a number of questions. First, it could help understanding of focus effects and set-building requirements in language processing. Focus is generally thought to deal with elements which are overtly stated in a sentence (e.g., as discussed in Birch, Albrecht, & Myers, 2000), but here with *no* and *only* the focused elements seem to be requiring the building of unspoken sets.

One possible way that people might be led to form one kind of contrast when they get *no* as opposed to another has to do with context. It is likely that context plays a role, and may even control which kind of contrast is made. Potentially influential contextual factors could include syntactic context, as well as prosodic context. Examples of each are given in (6) and (7) respectively.

6a). Teachers were the ones who went to the store, no students did.
6b). Going to the fair was what the students did, no students went to the store.

7a). No STUDENTS went to the store. Teachers did./?They went to the fair.
7b). No students went to the STORE. ?Teachers did./They went to the fair.

While future research could examine this question in more detail, our second experiment speaks to this question somewhat. The contexts used are highly conducive to making a contrast with the restrictor of the QNP, given that there is in half the cases a potential set to contrast with the restrictor set given in the context, while no clear contextual alternative exists in any condition for the predicate set. If context plays a role in which set *no* chooses to focus, we should expect in this case that people reading *no* would more often make a contrast with the restrictor set. Given that the data from *no* look similar to those from *only*, which always makes a contrast with the restrictor set, we can take this as tentative evidence for context playing a role in determining which set *no* focuses.

When considering the data from the *no* condition, however, the fact that the pattern was not as robust as with *only* should be addressed. One potential explanation has to do with the difference between sentential and adjectival negation. With the negation at the beginning of the sentence ("No professor likes beer"), both readings are possible (Koktova, 1986) —i.e., the one where "professor" is being negated as well as the one where "likes beer" is being negated. This ambiguity could provide an explanation as to why *no* can focus either the complement set or the other potential contrast set (see examples 5c-d). Using one of our stimulus sentences makes the problem of ambiguous negation even more clear—a sentence like "A bartender who no drinker generously tipped brought the drinks" could be true if no drinker tipped the bartender at all, or if no drinker *generously* tipped the bartender, though some drinkers may have given him small tips. Besides the different pattern of results from *only*, the ambiguous scope of the negation may further explain why the data for *no* on the adverb did not clearly follow the focus operator pattern—if the adverb is being negated for some people/on some trials, it may not have the same focus pattern, and thus the same results, as *only*. Future studies could include negation which was clearly either sentential or adverbial to see if the potential ambiguity is complicating the results for *no*.

Besides potentially informing questions of focus, negation, and providing information about three specific quantifiers, the results from the current experiments also have relevance for theories which posit costs for creating discourse elements as well as theories of costs due to integrating words over areas of a sentence which require referential processing. While *every* does not seem to require contrast set building, the results from *only* and *no* showing that having a contrast set in context reduces processing costs provide further support for theories hypothesizing costs for construction of discourse elements (e.g., as tested in Murphy, 1984). Another relevant theory which posits costs for referential processing is the Dependency Locality Theory (DLT—Gibson, 1998; 2000). It predicts that readers will have difficulty processing long structural dependencies, and be burdened more for dependencies which include more referential processing between their endpoints (Warren & Gibson, 2002). Effects due to extra processing in relative clause sentences should be seen on the embedded verb (because it is where the gap is processed) as well as the matrix verb (as it is the end of the matrix S-V dependency). In the current experiment, the target sentences used are the same in every condition—the only differences come about from restrictor set building (Expt 1) and contrast set building (Expt 2), both of which happen inside the dependency. In both experiments, there were some effects seen on both verbs such that having to build a set inside the dependency slowed processing. These findings, then, provide some support for the DLT.

One final relevant issue is the fact that sentence processing has long been an area in which results have been used to comment on the nature of the human sentence processing mechanism. More specifically, the results from this experiment are relevant to the question of incrementality. Incrementality (for a review, see Garrod & Sanford, 1999) refers to the idea that there is processing happening on each word, instead of all processing being delayed until a phrase or clause boundary. It was hoped that the experiments above would provide evidence for incrementality, but unfortunately, single-region contrasts were not significant in Experiment 2, although differences were found by region in Experiment 1. There are a couple of possible reasons for these findings. First, there could be a great deal of variance in the current data which would obscure single-region patterns. There is some evidence that large variances did contribute to the findings, because at least two other conditions, when compared to the *every, absent* condition (i.e., the condition likely to have the least variance as no contrast set building happens, and no extra sets are introduced in context), had marginally more variance than the *every, absent* condition. Also, it is possible that the processes associated with resolving quantifiers produce complexity effects that linger—producing more of a cloud of complexity than complexity localized to a single region. Cloud effects like this have been found in a recent study using a change detection task as a means to investigate the interaction of focus and semantic distance (Ward, Sturt, Sanford, & Dawydiak, 2003), although follow-up work has found that processing load seemed focused at the embedded verb (Sanford, A., Molle, Sanford, A.J., & Healy, 2004). The fact that the complexity effects we did find tended to last throughout several regions suggests that quantification may also produce complexity effects that are not localized. It is again a task for future research to distinguish between these possibilities of large variances and diffuse effects.

In summary, the results from the experiments reported in this paper speak to a number of issues. Besides providing information on the specific quantifiers used, the results are relevant to questions of focus and general quantification as well as sentence processing theories which discuss processing in terms of the costs involved, and also general issues of the architecture of the language processing system. In order to further understand these issues, there are a number of directions for future research. As discussed above, it is possible that *everyone* has a default interpretation, but that may be specific to *everyone* as it is a universal quantifier. Expanding this research using existential quantifiers could help determine whether *everyone* is alone in being default—a finding that would be relevant in understanding what gets assumed in discourse settings and thus does not have to be computed when processing language. A related issue in understanding quantification and sentence processing, as well as the interaction of those with discourse information has to do with how quantifiers are actually applied. In this paper, a basic model of quantifier processing was assumed, but more can be discovered about the time when the quantifier relationship is applied when processing quantified sentences. It could be applied all at once, using sets as entire groups, or it could be a more individuated process, where entities in the sets are mapped one at a time. The relationship may also vary by quantifier. Finally, including different quantifiers in future experiments could help us understand more about what kinds of information interact at what point during processing. The meaning differences between different kinds of quantifiers could show how processing interacts with semantic information, as well as discourse information. Testing with more sensitive methodologies could then speak to the timecourse of the various interactions, and perhaps inform larger, more general theories of sentence processing as well as theories of the architecture of the language system.

References

Aldridge, M. V. (1982). *English quantifiers: A study of quantifying expressions in linguistic science and modern usage.* England, Avebury Publishing Company.

Almor, A., & Eimas, P. (2000). The time course of focus effects in spoken sentence comprehension. Poster presented at the *13th annual CUNY conference on human sentence processing.* San Diego: CA.

Altman, G., & Steedman, M. (1988). Interaction with context during human sentence processing. *Cognition, 30*, 191-238.

Birch, S. L., Albrecht, J. E., & Myers, J. L. (2000). Syntactic focusing structures influence discourse processing. *Discourse Processes, 30*, 285-304.

Chafe, W. (1972). Discourse structure and human knowledge. In J. B. Carroll & R. O. Freedle (Eds.), *Language comprehension and the acquisition of knowledge*. Washington: Winston.

Chater, N., & Oaksford, M. (1999). The probability heuristics model of syllogistic reasoning. *Memory & Cognition, 6*, 481-490.

Crain, S., & Steedman, M. (1985). On not being led up the garden path: The use of context by the psychological parser. In D. Dowty, L. Karttunen, & A. Zwicky (Eds.), *Natural language processing: psychological, computational, and theoretical perspectives* (pp. 320-358). Cambridge: Cambridge University Press.

Cushing, S. (1982). *Quantifier meanings: A study in the dimensions of semantic competence.* Amsterdam, NY, North-Holland Publishing Company.

Ferreira, F., & Clifton Jr., C. (1986). The independence of syntactic processing. *Journal of Memory and Language, 25,* 348-368.

Frazier, L. (1978). *On comprehending sentences: Syntactic parsing strategies*. Ph.D. dissertation, University of Connecticut.

Garrod, S. & Sanford, A. (1999). Incrementality in discourse understanding. in H. van Oostendorp & S. R. Goldman (Eds.), *The construction of mental representations during reading* (pp. 3-27). Mahwah, NJ: Erlbaum.

Gibson, E. (1998). Linguistic complexity: Locality of syntactic dependencies. *Cognition, 68,* 1-76.

Gibson, E. (2000). The dependency locality theory: A distance-based theory of linguistic complexity. In Y. Miyashita, A. Marantz, & W. O'Neil (Eds.), *Image, language, and brain* (pp. 95-126). Cambridge, MA: MIT Press.

Gordon, P. C., Hendrick, R., & Johnson, M. (2001). Memory interference during language processing. *Journal of Experimental Pscyhology: Learning, Memory, and Cognition, 27,* 1411-1423.

Grodner, D. J., Gibson, E. A. F., & Watson, D. G. (in press). The influence of contextual contrast on syntactic processing: Evidence for strong-interaction in sentence comprehension. *Cognition*.

Heim, I., & Kratzer, A. (1998). *Semantics in generative grammar.* Oxford: Blackwell.

Jespersen, O. (1933). *Essentials of English grammar.* London: Allen & Unwin.

Just, M. A., & Carpenter, P. A. (1971). Comprehension of negation with quantification. *Journal of Verbal Learning and Verbal Behavior*, *10*, 244-253.

King, J., & Just, M. A. (1991). Individual differences in syntactic processing: The role of working memory. *Journal of Memory and Language, 30,* 580-602.

Koktova, E. (1986). *Sentence Adverbials*. Amsterdam: John Benjamins.

Kurtzman, H. S., & MacDonald, M. C. (1993). Resolution of quantifier scope ambiguities. *Cognition, 48,* 243-279.

MacDonald, M. C., & Just, M. A. (1989). Changes in activation levels with negation. *Journal of Experimental Psychology: Language, Memory, & Cognition, 15,* 633-642.

McCawley, J. D. (1993). *Everything that linguists have always wanted to know about logic but were ashamed to ask.* 2nd ed. Chicago: University of Chicago Press.

Micham, D., Catlin, J., VanDerveer, N., & Loveland, K. (1980). Lexical and structural cues to quantifier scope relations. *Journal of Psycholinguistic Research, 9,* 367-377.

Moxey, L. M., & Sanford, A. J. (1987). Quantifiers and focus. *Journal of Semantics, 5,* 189-206.

Moxey, L. M., Sanford, A. J., & Dawydiak, E. J. (2001). Denials as controllers of negative quantifier focus. *Journal of Memory and Language, 44,* 427-442.

Murphy, G. L. (1984). Establishing and accessing referents in discourse. *Memory & Cognition, 12,* 489-497.

Ni, W., Crain, S., & Shankweiler, D. (1996). Sidestepping garden paths: Assessing the contributions of syntax, semantics, and plausibility in resolving ambiguities. *Language and Cognitive Processes, 11,* 283-334.

Oaksford, M., Roberts, L., & Chater, N. (2002). Relative informativeness of quantifiers used in syllogistic reasoning. *Memory and Cognition, 30,* 138-149.

Paterson, K. B., Liversedge, S. P., & Underwood, G. (1999). The influence of focus operators on syntactic processing of short relative clause sentences. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 52A,* 717-737.

Paterson, K. B., Sanford, A. J., Moxey, L. M., & Dawydiak, E. (1998). Quantifier polarity and referential focus during reading. *Journal of Memory and Language, 39,* 290-306.

Sanford, A., Molle, J., Sanford A. J., & Healy, N. (2004). *Shallow semantic processing of spoken utterances.* Poster presented at AMLaP, Université d'Aix en Provence, France.

Sanford, A. J., Moxey, L. M., & Paterson, K. B. (1994). Psychological studies of quantifiers. *Journal of Semantics, 10,* 153-170.

Sedivy, J. C. (2002). Invoking discourse-based contrast sets and resolving syntactic ambiguities. *Journal of Memory and Language, 46,* 341-370.

Ward, P. Sturt, P., Sanford, A., & Dawydiak, E. (2003). *The effects of linguistic focus and semantic distance on eye movements in a text-change detection task.* Poster presented at AMLaP, Glasgow, Scotland.

Trueswell, J. C., Tanenhaus, M. K., & Garnsey, S. M. (1994). Semantic influences on parsing: Use of thematic role information in syntactic disambiguation. *Journal of Memory and Language, 33,* 285-318.

Villalta, E. (2003). The role of context in the resolution of quantifier scope ambiguities. *Journal of Semantics, 20,* 115-162.

Warren, T. (2003). The processing complexity of quantifiers. In L. Alonso-Ovalle (Ed.) *Umass Occasional Papers in Linguistics 27: On Semantic Processing,* 211-237.

Warren, T., & Gibson, E. (2002). The influence of referential processing on sentence complexity. *Cognition, 85,* 79-112.