UNIVERSITY OF SOUTHAMPTON

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Psychology

Investigating the Influence of Boundedness and Negation During Reading

by

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ABSTRACT

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It has previously been suggested that a bounded adjective (e.g., dead) must be interpreted as its antonym (e.g., alive) when negated (e.g., not dead), in contrast, unbounded entities (e.g., wide) when negated, an unbounded entity (e.g., not wide) can refer to multiple states and is not necessarily interpreted as its antonym (e.g., narrow). How readers interpret such expressions is largely unknown. Accordingly, the research within this thesis investigated the processing of boundedness in four experiments. Experiment 1a-c used off-line judgment tasks to assess whether readers were sensitive to boundedness when judging negated sentences. These showed readers judged bounded negation as similar to its antonym, whereas unbounded negation is seen as being less similar than their antonym. Experiment 2 used eye movements to investigate on-line processing of boundedness. Experiment 3 examined the influence of bounded on the facilitatory effect of connectives on establishing discourse coherence. Experiment 4 investigated the specificity of representations of bounded and unbounded negation. By measuring eye movements, we can gain insights into the on-going cognitive processing that is occurring during the reading of text. Eye movements have been used extensively to help us to understand the cognitive processing that occurs during reading, but there has been very little research into how our reading differs when we read bounded and unbounded negation. In this thesis the influences of boundedness on reading is examined. Bounded items appear to be interpreted as categorical, whereas unbounded items are interpreted in a more ambiguous manner. These experiments are the first to provide evidence that boundedness has an early influence on the online processing of negation during natural reading.

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Academic Thesis: Declaration Of Authorship

I, *Lewis Jayes* declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

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I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. None of this work has been published before submission.

Signed: ……

Date: ……

Acknowledgements

"Ladies and Gentlemen, I'm going to prove to you not only that Freddy Quimby is guilty, but that he is also innocent of not being guilty."

Lionel Hutz, 1994

In lieu of the philosophical ramblings of a man paying homage to his own sense of indebtedness, I dedicate this section to all of those who provided positive interaction during my PhD.

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Chapter 1

The Influence of Negation and Boundedness on Language Comprehension

General Introduction: Negation and Boundedness

Grice (1975) proposed several 'conversational maxims' that he suggested communicators use in order to achieve successful and informative exchange of information. Within these, and particularly within the maxim on quantity, he suggested that communicators possess a preference for expressions that incorporate all relevant information parsimoniously, i.e. as efficiently as possible. Ostensibly, that is not the case when using negation, the use of markers to reverse the meaning of a predicate (Horn, 1984). For instance, comprehending "*not early*" is less parsimonious and more cognitively demanding than "*late*" (Carpenter & Just, 1975), yet both are felicitous (semantically and pragmatically coherent within the linguistic context it is used) within normal language. The topic of negation, expressing an opposite or absence by placing a concept within a negators' scope, has been an area of psycholinguistic research for over half a century. Negation serves multiple functions (Horn, 1989); these include the ability to deny/reject a proposition (e.g. *Peter did not buy the book*) or deny prior expectancies (e.g. expressing *the train is not late*, when it normally is). These functions appear to involve the comprehender reversing the polarity of the statement in order to comprehend the negated statement. Other functions of negation include delivering metaphorical meaning (e.g., *they're no angel*) and to generate a politer assertion (e.g., *John is not smart is more polite than John is stupid*) (Colston, 1999; Giora, 2006). With these functions, it can be seen how readers cannot successfully interpret the text by simply reversing the meaning of the predicate that has been negated, as the true meaning cannot be seen in just the surface text.

The anthropologist Donald Brown (1991; 2000) listed the logical concept of negation as a 'human universal', indicating that there has yet to be a known language or culture within which negation has not featured. This suggests negation is a necessity to language and communication rather than a semantic superfluity. The way

in which negation is incorporated into a reader's discourse representation, however, remains a fairly heated debate. In order to truly understand how humans process language, we need to understand the different variables that impact on how negation is processed. This remains a relatively unexplored part of psycholinguistics.

Traditional theories viewed negation as a simple grammatical process where the polarity of the negated statement is reversed. In these traditional theories, mental representations of objects and the relationship between objects take the form of symbols. In the case of negation, to represent the triangle is not above the star, the reader has to instantiate the symbols for triangle and star with the relevant logical relation of above, this must then be 'mentally suppressed' to instantiate an accurate representation. A subsequent series of studies reported that processing negation (the triangle is not above the cross) is significantly slower than its affirmative equivalent (the triangle is above the cross) due to this added logical relation (Carpenter & Just, 1975; Chase & Clark, 1971; Clark & Chase, 1972; Just & Clark, 1973; MacDonald & Just, 1989). The implication of these findings being that negation is always more difficult to process than an affirmative equivalent as there is an extra grammatical process required (reversing the polarity of the negated statement).

There is a prevailing view, however, that a range of linguistic constraints, such as familiarity with the concept being negated and common knowledge (Ginzberg, 2012), affects the comprehension of a negated concept (Giora, 2005).
While previous theories only sought to explain the role of negation as a way of denoting an absence, it has become increasingly accepted that theories of negation must account for the multiple functions that negation serves. Indeed, it would appear that readers are capable of instantiating a negated representation that is not just a reversed polarity version of the text. For instance, not hot does not necessarily mean cold (Fillenbaum, 1966; Paradis & Willners, 2006), it simply refers to a state away from hot. Brown (1991; 2000) also referred to the human universal of differentiation between binary/dichotomized items (e.g., *dead/alive*) where the concept only has two possible states of existence and scalar items where the concept possesses multiple states along a scale (e.g., the scale *hot/cold* also features a range of heats like *warm/chilly/freezing* etc.). It has been suggested that in the former case negation does reverse the polarity of the negated concept, as not dead does equal alive, but this

is not the case for scalar concepts, as it can also be said that not hot does not necessarily equal cold (Ladusaw, 1996).

This distinction of concepts has been expanded upon to introduce the linguistic operator of boundedness. A concepts' semantic configuration refers to the number of states possible within that dimension. Boundedness is used to define the nature of this configuration. This definition considers the relationship between the two antonyms within a dimension, antonyms being two polar opposite lexical items (e.g. *dead/alive, hot/cold*). Bounded dimensions only feature two mutually exclusive and mutually exhaustive states (e.g. *dead/alive* as there are no reasonable states in between these two). When negated, therefore, bounded items can only refer to their antonym. For instance, with the pair *dead* and *alive*, no other possible state exists and *not dead* can only refer to the state of *alive*. This is compared to unbounded antonym pairs that exist within an open scale with many possible states between the two antonyms. For instance, between *hot* and *cold* many states of heat are possible. As such, the negation of an unbounded antonym does not necessarily refer to its antonym. *Not hot* can refer to many states besides *cold*. The notion of boundedness has been used to suggest we conceptualize our world around this distinction. The experiments within this thesis explore whether readers are capable of making complex calculations about these concepts being used in language. For instance, in order to calculate the ambiguity of an unbounded negation, a comprehender must be able to consider the number of possible states within that concept. The experiments within this thesis will not only explore whether readers comprehend these differences, but whether they are sensitive to these categorizations on-line during language comprehension.

The aim of this thesis was to investigate the effect of the linguistic operator of boundedness during language comprehension. Unlike most of the previous negation literature, where offline questionnaires and reaction time verification tasks were utilized to investigate the instantiation of negated representations, the experiments here feature eye tracking. Eye tracking measures of reading are non-invasive, with reading times providing an objective measure of on-line lexical, syntactic and semantic processing (Inhoff & Rayner, 1986; Rayner, 1998). Advances in the last 30 years have clearly shown that the physiology of the eyes and their movements are directly coupled with the online psychological processes underlying them (Liversedge

& Findlay; 2000; Rayner, 1998). The length of a fixation (and number of fixations) on a word is directly related to the processing difficulty associated with that word (Frazier & Rayner, 1982).

An outline of several relevant accounts for the processing of negated utterances will be discussed within this review, as well as the linguistic and experimental data collected from investigations of how the linguistic operator of boundedness operates during comprehension. This review also outlines the importance of on-line eye movement experiments, an insightful, but underused methodology within this particular area of psycholinguistic literature, which allows for the investigation of the effect of negation and how its ambiguity affects the instantiation of a discourse representation. Many aspects of negation are explored within this thesis. Chapter 2 explores whether readers are sensitive to boundedness when making offline, similarity judgments. Chapter 3 explores whether readers are sensitive to boundedness during on-line processing of text. Chapter 4 explores the effect of boundedness on the facilitation provided by connectives. Finally, Chapter 5 explores the nature of unbounded representations and readers' default representation of unbounded negation. Furthermore, these experiments are among the first to investigate negation and boundedness as an online linguistic operator during language comprehension.

Accounts of Negation Comprehension

While negation refers to the way in which a negative operator reverses the state of events expressed (Horn, 2001), the cognitive processes underlying this computation remain heavily debated. In this section, the development of theories of processing negated concepts will be described. Furthermore, it will be shown how the advancements of these theories has required researchers to take into account an increasing number of contexts where negation can be used. The cognitive implications of negation appear to show an increased complexity when compared with affirmation (Clark & Chase, 1972). For example, *it is juice* denotes exactly what an object in question is. The sentence *it is not juice* in isolation has comparatively little informative power in discerning what an object is. Subsequently, this has led to theories of negation based on the slower processing of a negated entity, as readers

must accommodate the lack of specificity of a negation. Subsequently, theories have advanced and attempted to explain the processing of negation largely based on the context within which it is used. If negation were such an inefficient means of communication, it would be at odds with its prevalence within language (Giora, 2006). Recent theories of negation have considered, therefore, why it is such a useful resource for the communicator while also understanding negation will tend to be more ambiguous than denoting an affirmative equivalent.

Propositionalist Accounts of Negation Comprehension

Within propositionalist accounts of language comprehension the proposition is held as the most important unit of semantic interpretation, and it has been proposed that working memory stores incoming linguistic information at a propositional level, as opposed to on a word-by-word basis (Kintsch & Keenan, 1973). A proposition is defined as "a predicate and one or more arguments" (Van Dijk & Kintsch, 1983, p.113), for example, in the sentence, *Geese crossed the horizon as wind shuffled the clouds*, there are two propositions, *geese crossed the horizon* and *wind shuffled the clouds* related by a logical connective (*as*). The predicates of each proposition are *crossed* and *shuffled*, with *geese, horizon* and *wind*, *clouds* acting as arguments acting according to the predicate. From here, the fundamental meaning of the proposition is integrated into their discourse representation in a much simpler, symbolic form. For example, the previous example would lead to two propositional representations, often written in propositional calculus to denote the symbols within each representation and their relationship. In the example, the first proposition would be represented as (crossed (geese, horizon)), as *crossed* is the predicate acting upon the two arguments, while the second proposition would be represented as (shuffled (wind, clouds)). These representations are more efficient than storing the words verbatim. Those propositions that are thematically crucial to comprehending the text are referred to as "macropropositions" (Kintsch, 1974).

Macropropositions have been found to be the most resistant to decay in memory when comprehension of text was tested over three months (Kintsch & Van Dijk, 1978). For instance, consider the relatively complex sequence of propositions: *Mary went to the airport. She took a taxi. She checked in for the flight to Paris. She went to the gate.* The macroproposition in this case would be *Mary flew to Paris*, upon

which all other propositions are reliant to form coherent discourse (Van Dijk, 1980). Within propositional theories of language, content is represented symbolically, rather than pictorially or in its original linguistic form. These symbols are amodal and abstract, they represent content conceptually regardless of the sensory modality related to its perception (Pylyshyn, 1973). Furthermore, these symbols can be manipulated according to any semantic and grammatical possibility, allowing for virtually infinite possibilities within utterances.

Historically, propositional theories of language have been seen as a backlash against simple associative theories of language (Bloom, Hood & Lightbrown, 1974). Within associative theories of language, language is acquired and used according to imitation, reinforcement and reward. Propositional theorists argued associative explanations of language were unable to account for the true complexity of human cognition, particularly in language where combinations of words are, arguably, infinite (Chomsky, 1971; Pylyshyn, 1973). Not only was reinforcement argued to have a minimal impact during language development, but the frequency with which novel constructions are uttered and immediately understood (Chomsky, 1959) suggests language processing requires the ability to manipulate the concepts that language presents. The language system was suggested to only be capable of this when propositional content is represented symbolically.

Early cognitive accounts of negation were formed from this early theoretical view of language comprehension through semantic propositional representations. Early propositionalist accounts posit that the concept within a negator's scope is mentally encapsulated and suppressed and, therefore, made inaccessible (Carpenter & Just, 1975). This relatively simple account argues suppressing a negated concept causes an interpretation of the text within which the negated item is not present. For instance consider sentence 1:

1. Mary bakes bread but not cookies

According to the propositional account, the concept of the *cookies* is suppressed due to the negative operator, and at a propositional level the suppression of *cookies* leaves *bread* as the dominant argument. This was formulated based on findings from Clark and colleagues (Chase & Clark, 1971; Clark & Chase, 1972; Just & Clark, 1973). Participants in this set of studies were tasked to assess the truth-value

(*yes/no* response) of sentences such as ''*the star is not above the cross*" via a picture probe. They found assessing the truth-value of a picture took a significantly longer amount of time when the sentence was presented in the negative form compared to its affirmative form. It was suggested that this is due to the increase in mental operations required for comprehension. Specifically, the extra processing stage of mentally encapsulating and suppressing a negated concept, followed by the usual propositional representation of information. This caused comprehenders to take longer to instantiate representations that had been negated. Furthermore, it was suggested that this was a serial process as comprehenders move through the text deriving meaning proposition by proposition (Kintsch, 1988).

Just and MacDonald's (1989) follow-up experiment used a sentence-picture verification task to investigate the processing of negated and affirmative statements. Following each sentence, participants were presented with either a picture of the affirmative, negative or unrelated entity and had to decide whether it was present in the sentence. When presented with a sentence such as sentence 1 above, reaction times were significantly longer in responding to a picture of the negated entity: *cookies* when compared with the affirmative entity picture: *bread*. The propositionalist theorists would argue this was because the negated entity had been suppressed from the reader's mental representation and the concept was now inaccessible. Within this account, a representation of the sentence *the door is open* would be detailed as (Open (Door)), with open being the predicate acting upon the state of the door. In the negated case, however, an additional relation needs to be instantiated within that representation. The sentence *the door is not open,* would be represented as NOT (Open (Door)). The two propositions only differ in the placing of a logical operator over the proposition in the latter case. In this case, a negative operator that signals for the suppression of any content within its scope. This series of studies showed a consistent cost in retrieving the semantic content of negated propositions compared to their affirmative equivalents. These findings provided great support for propositional theories of negation as a process of suppression.

In summary, propositional accounts of negation have been used to support the notion that readers extract the general meaning of text through propositions represented symbolically, rather than exact representations. In the case of negation, these discrete symbols place a negative operator over the negated concept, a process

that always takes longer due to the increased number of mental operations required. This account is supported by research indicating that comprehending the truth-value of a negated proposition took significantly longer than did comprehension of their affirmative equivalent (Chase & Clark, 1971; Clark & Chase, 1972; Just & Clark, 1973; Just & McDonald, 1989). The next section details how these affirmative "equivalents" represent an inappropriate comparison to negation when used in null context and the theoretical implications of this assertion will be discussed.

Two-Step Theories of Negation Comprehension

Situational accounts, such as two-step theory, provided theoretical opposition to classic accounts of processing negation based on the fact that supporting evidence is only present for "null context" negated sentences. Findings as early as Wason's (1961, 1965; Wason & Jones, 1963) have shown that by providing the right pragmatic context, negated sentence primes actually facilitate similar/dissimilar picture judgments. This was shown by faster reaction times for negated propositions within picture sentence verification tasks when context was pragmatically felicitous for the expressing of negation that when it was not. For instance using sentence 2:

2. *The train was not late*

The representation of the concept of the *train* is more readily accessible within a context where the speaker's train is usually late. As the negation is denying an expectation of a *late* train, the negation is motivated and readers can understand the use of negation more quickly than if it is used without motivation. This finding inspired what now has become known as the exceptionality hypothesis. De Villiers and Flusberg (1975) defined this kind of negation scenario as a "plausible negative": the use of negation to communicate a discrepancy between the listener's expectation and fact, such as sentence 2 in the context of a usually *late train*. Furthermore, they found plausible negatives are understood at a significantly younger age in child development than negation presented without context or motivation. It has even been suggested that plausible negatives are required for children to understand the grammatical nature of negation. Thus negation appears

to serve one of many purposes in language, in this case to deny an expected state. It is this purpose that children must understand before they develop the ability to use and understand negation.

Furthermore, Johnson-Laird and Tridgell (1972) provided one of the earliest findings to suggest that negation is not universally slower to process than affirmation. They found that when two possibilities have been presented (e.g., *Either John is intelligent or rich*), readers comprehend the subsequent negation (*John is not intelligent)* quicker than affirmation (*John is poor*). The contextual sentence provides the assertion that there is a categorical distinction to be made about *John* he can only be one of *intelligent* or *rich.* This allows the reader to instantiate a clear state for the negation, if *John is not intelligent,* he must be *rich;* a single, unambiguous representation has been provided by the context for the subsequent negation. That negation can, therefore, be instantiated quicker than if the negation appeared without the context, *John is not intelligent* does not provide an unambiguous representation with which to describe *John.* As such, when provided with the contextual sentence, participants responded quicker to *John is not rich*, than to *John is rich*. This early data was some of the first to suggest that processing negation is not necessarily slower than affirmation. Rather, coherent use of negation requires the fulfillment of several pragmatic expectations during its communication, unlike the use of affirmative equivalents, which communicate definitive aspects of a situation. This is because negated sentences are more inherently and structurally ambiguous than their affirmative counterparts and require presupposed information in order to be used efficiently. As previous propositional studies did not meet this requirement, a delay in the processing of negation was always found.

The role of context in the understanding of negative sentences has been an important variable for manipulation in subsequent pragmatic research. After several failed attempts (Arroyo, 1979; 1980), Arroyo (1982) was able to find supporting evidence for the exceptionality hypothesis by giving an oddity problem to participants. In this paradigm, participants were presented with four words, one of which was considered discrepant from the others. For instance, they were presented with the four items *Miami, Dallas, Chicago* and *Paris*, followed by a statement about a member of the set. For instance, *Paris is (not) an American city*, or *Miami is (not) a*

French city. They manipulated whether the entity in the question was negated or not and participants had to state whether it was true or false. The typical delay in processing and verifying negated statements was alleviated when the negation contrasted and distinguished an exception. Participants were significantly faster to respond that *Paris is not an American city* in the previous example than they were to respond that *Miami is not a French city*. Due the contrastive focus negation provides, it can be processed efficiently when that contrast is easily perceived, as it is recognizably coherent to use that negation. The task here met this criterion as it forced participants to perceive the contrast with the other items; a stipulation not fulfilled in previous picture verification tasks. As participants were presented with four separate entities with one clear exception, participants were primed to the contrast about to be made by the negated sentence. When negation was used suitably, it alleviated the delay previously seen in processing negation negation. In this case, when negation was used to indicate a very obvious contrast, participants rapidly comprehended the negation.

Wason (1965) had participants complete sentences following presentation of a visual stimulus, such as eight numbered circles, seven of one color (e.g. *red*) and one of another (e.g. *blue*). Participants were then presented with sentences to describe the circles which features a negation or not (e.g. *circle no.3 is ….* Or *circle no. 3 is not …*). Wason found participants were faster to complete a negated statement when it referred to the exception circle. To be clear, if *circle no 3* was the one red circle out of eight, participants were faster to complete the sentence than if *circle no 3* was one of seven blue ones. As the red circle was exceptional, it was suitable to negate the color of it, in order to draw attention to its exceptionality.

Clearly, isolated picture-sentence verification tasks that featured negation without pragmatic motivation or context have failed to truly test how readers normally instantiate negated representations during language comprehension. Rather, they show how negation, in isolation, is structurally ambiguous and not an efficient means for presenting information (Givon, 1978). Without providing contextual reasoning for its use, negation will be processed more slowly as it does not denote a specific representation to instantiate. If experiments do not use this

contextual reasoning are not presenting negation, as it would be used during typical language, limiting the validity of the results.

Glenberg, Robertson, Jansen and Johnson-Glenberg (1999) conducted an experiment using a self-paced reading task to measure reading times for sentences in their negated or affirmative form (Sentence 5). This followed a context, which had either invited the contrast made by the negated sentence (Sentence 3) or one that did not (Sentence 4).

3. Supportive Context - *She wasn't sure if a darkly **coloured** couch would look the best. She finally picked one out and had it delivered to home.*
4. Non-Supportive Context - *She wasn't sure what **kind of material** she wanted the couch to be made of. She finally picked one out and had it delivered to home.*
5. *The couch was (not) black*

If the role of pragmatic context were not an important variable in extracting meaning from negated sentences, it would not matter whether the preceding context supported the contrast that the negated sentence made. Thus reading times for Sentence 5 would be slower in the negated condition regardless of which context was used (supportive or non-supportive). In contrast, Glenberg et al. found longer reading times for the negated sentence within the experimental items when the context did not support the contrast made (Sentence 4) compared to when it did (Sentence 3). Furthermore, they found reading times for supportive context negations to be no longer than in the affirmative conditions. These findings cannot be explained using propositional theory, where it was proposed that negative propositions more slowly represented than their affirmative counterparts. Without a supportive pragmatic context, negations present a greater variety of situations due to their inherent structural ambiguity. Readers can easily interpret a negation when they have been informed there is a possible contrast to be made (e.g., how dark the couch is). This allows negation to be processed at the same speed as an affirmative equivalent.

Two-step theory emerged as a reaction to these studies showing that propositional theory cannot fully account for the processing of negation. Two-step

theory (Kaup, 2001) features two divergences from previous, propositional theories. Firstly, it suggests that readers, upon encountering a negated entry, generate more than one simulation of the linguistic input in order to extract meaning. Specifically, readers initially generate the proposition without negation, for example *the eagle is not in the sky* is represented as *the eagle is in the sky.* A negative marker is then mentally placed upon the concept, allowing for an accurate representation of discourse (*the eagle is not in the sky)*. This second step creates the delayed time course for representing negated statements compared to affirmative equivalents.

Secondly, the way in which language is represented is significantly different from propositional theory. In the case of an affirmative proposition, propositional theory would argue for an amodal set of symbols encoded within proportional representations. This is compared to two-step theory, which argues representations from language are grounded in its sensorimotor experience. Representations, therefore, are equivalent to the sensorimotor experience of the propositional content (Spivey, 2007). For instance, *the eagle in the sky* primes recognition of an image of an eagle with outspread wings, as the statement presents a clear representation that can be instantiated. In the case of a negated proposition such as *the eagle is not in the sky* however, an image of an eagle with closed wings is not primed (Kaup, 2001). It was argued that this is because that is not explicitly stated with the negation, which is ambiguous about the state of the *eagle*. It was argued, therefore, that there is no visual experience to map to that negated sentence, leading to a lack of a priming effect. As previously seen, of course, it could be argued that this sentence in isolation is not sufficient to correctly represent the state of the *eagle* referred to.

Two-step theorists have argued that because negation leads to the generation of multiple simulations, the formation of negated representations features different underlying processes that occur with a different time course (as discussed below). Two-step theory is experiential in nature; in order to extract linguistic information, an equivalent sensorimotor simulation is generated into a discourse representation, containing all necessary information. For the sentence, *the eagle is in the sky,* it would be argued within a two-step theory that some visual representation of this event would be represented in order to comprehend the text. Negation is not considered as a simple

grammatical process within two-step theory, but signals to the reader the need to consider multiple experiential representations. This chapter will now review the findings to support this theory.

The two-step theory primarily relies on simulations of linguistic information being experiential. This will now be outlined in order to elucidate the theoretical position of two-step theory. Zwaan (2004) refers to the "immersed experiencer framework" of sentence processing within which these experiential representations operate. According to this framework, words activate experiences with their referents. For example *an eagle in the sky* activates a visual experience of an eagle with stretched- out wings while *an eagle in the nest* activates a different, relevant visual experience. Neurobiology findings showing an overlap of activation between linguistic entities and their non-linguistic counterparts (perception or action of the verb) (Pulvermüller, 1999, 2002) detailed a wealth of neuropsychological findings during language acquisition and subsequent language processing in support of this framework. The results can be summarized as showing that the activation of neuronal distributions during perceptual experience are strongly correlated with activation during the processing of their equivalent linguistic form. This includes visual cortex neurons that fire to lexical items and their perceptual equivalent and assemblies of neurons in the motor cortex that fire to the relevant verbs (i.e. reading *kick* activates motor neurons used when kicking). Furthermore separate assemblies of neurons that correlate with function, abstract and concrete content words respectively have been demonstrated. While this could be taken as showing an undeniable link between cognition and action (Goldinger, Papesh, Barnhart, Hansen & Hout, 2016), within two-step theory this is taken to assume that the coupling of neural activity with linguistic, motor and sensory representations makes the sensorimotor embodiment of language "unavoidable" (Spivey, 2007). Furthermore, as it is argued that negation cannot have a embodied referent, as negation in isolation is wholly underspecified, it has been argued that negation must be first be simulated in its affirmative form, thereby creating a sensorimotor equivalent, which can be suppressed. One argument against his could be the notion that, as has been shown by studies into the exceptionality hypothesis, negation is rarely used just to signal an absence of a referent. It is often used to draw attention to an aspect that is

considered exceptional, for instance. Furthermore, negation does not necessarily need to be as ambiguous as it has been presented in these examples. *The patient is not alive* presents a very clear referent of someone who is *dead.*

Nevertheless, evidence for representations being experiential in nature is further grounded in the evidence of faster processing of negated entities when they are still present within the situational representation (Kaup & Zwaan, 2003). It can be argued that the negated entity in the case of sentence 6 can generate an explicit perceptual simulation, as the item that has been negated is still present within the situational representation. In the case of sentence 7, however, the item being negated is not present within the situational representation; therefore it has no direct sensory referent.

6. *Sam wished that Laura was not wearing her pink dress*

7. *Sam was relieved that Laura was not wearing her pink dress.*

In the case of sentence 7, the description cannot explicitly capture the actual state of Laura's attire, as, without context, it does not provide a definitive state regarding Laura's dress. Kaup and Zwaan (2003) explored accessibility to the negated concept by a word probe (having to indicate whether the color word probe presented was featured in the sentence) either 500 or 1500 ms after reading the sentence. After 500 ms, they found negated sentences were always responded to more slowly than affirmative sentences. After 1500 ms, however, participants were only slower to respond to word probes having reader sentence 7, compared to sentence 6.

It was argued that sentence 6 does capture the state of her attire, as it clearly infers she is wearing a *pink dress*, meaning it can produce a directly relatable, experiential representation. This resulted in a faster successful instantiation of the negated representation, evidenced by faster response times. Whereas, in the case of sentence 7, it is suggested that any experiential representation has to be subsequently suppressed in order to reach a successful instantiation of discourse. They suggest this provides support for the notion that only negated items with an embodied referent can be processed quickly. They suggest all affirmative items have a referent, as they are present within the discourse representation being instantiated. With negated items, however, this is not always the case, as they can refer to items that are not

present within the situational model, such as in sentence 7. In the case of sentence 6, however, there is a clear representation to instantiate as the *pink dress* is present, and the negation refers to a wish on the part of *Sam* for an absence of the *dress,* rather than to the absence of the *dress* itself. They suggest, therefore, that comprehending negation must use other mechanisms to represent discourse, specifically the representation of its affirmative equivalent, followed by suppression.

Hasson and Glucksberg (2006) provided supporting evidence relating to the time course of two-step negation processing by manipulating the interstimulus interval (ISI) between the presentation of a contextual sentence prime and a word probe in a lexical decision task. Sentences were either negated or affirmative (sentence 8) and were followed by a probe word, which related to the affirmative or negative version of the sentence. In this case *fast* is related to the affirmative version, whilst *slow* is related to the negative form.

8. *The train to Boston was a/no rocket.*

According to two-step theory, readers initially generate the core proposition, in this case that *the train is a rocket* and therefore *fast*, before applying a negative marker upon the concept within the negative operators scope, that *the train was no rocket* and, therefore, *slow*. This inhibits the activation level of the concept within the core supposition (*speed*). Hasson and Glucksberg used ISIs between the prime and the probe of either 150ms or 1000ms. According to two-step theory, at the short interval, in this case 150ms, readers only have time to represent the situation in its affirmative form and have yet to apply a negative marker. A longer ISI of 1000ms, however, is sufficient for the comprehender to have represented both the affirmative and negated interpretations. The actual state of affairs (the negated simulation) will, therefore, be the dominant interpretation of the text's meaning by 1000ms, whereas the affirmative version is still the dominant interpretation at 150ms.

Hasson and Glucksberg found in their lexical decision task that the negative prime condition (*no rocket*) yielded faster RTs to the affirmative probe (*fast*) at 150ms than to the negative probes (*slow*). At 1000ms, participants were now faster to respond to probes that were related to the negative prime (*no rocket - slow*) than

to the positive prime (*fast*). These results were taken to show that at 150ms, the dominant simulation was one without the negative marker; meaning *fast* was the dominant concept within the mental representation. This was shown by *fast* being primed at 150ms, even when the sentence referred to a slow train. This was defined as a serial process; the simulation with the negation term fully computed could not, therefore, be dominant until after this initial simulation, which had occurred by 1000ms. By this point, the negative marker had reduced accessibility of the affirmative representation prompting the correct interpretation of the negation. These results were taken as evidence of a two-step process when comprehending negation.

Similar patterns of results were found when the behavioral probe was replaced with images representing the negative or affirmative version of events in a sentence picture verification task with ISIs of 750ms and 1500ms (Kaup, Ludtke & Zwaan, 2006). Such a time course is taken to further convey that negation processing is split into two distinct steps. Within these studies, the picture verification task continues to make a significant contribution to the negation literature. This is despite the apparent flaws of this methodology, namely that it does not account for the pragmatic factors required for negation to be used felicitously (e.g., exceptionality: Arroyo, 1982; Wason, 1965). Two-step theorists have used differential patterns of results at different ISIs (Hasson & Glucksberg, 2006; Kaup & Zwaan, 2003; Kaup, Ludtke & Zwaan, 2006) to explain how negation is different from affirmation; specifically that it often cannot have a direct sensorimotor representation, as it signals an absence.

Ferguson, Sanford and Leuthold (2008) used eye tracking and ERP measures to investigate negation processing within counterfactual settings. Eye tracking was used to assess when readers were able to recognize anomalies within the text (see Rayner, Warren, Juhasz & Liversedge, 2004). Participants were presented with a negated context, in opposition to reality (item 9: *not carnivores*) followed by target sentences that were congruent (10, 1) or incongruent (10, 2) with this negated or affirmative context.

9. *If cats were (not) carnivores…*

10. *Families could feed their cats a bowl of carrots* (1)/*fish* (2)

When the target sentence was incongruent with the negated context (10, 2), reading measures were used to show that a disruption to processing, specifically regressive eye movements back in the text, began much later than when the target sentence was incongruent with the affirmative real world context (10, 1). The authors argued all text is evaluated against our real world knowledge, before being evaluated against the discourse context that had been created. This delay can certainly be explained within a two-step account, as detection of the anomaly was relatively late, suggesting a delay in access to the negated entity.

One possible confound in this study was the use of counterfactual information within the context of the negation use, as accessing counterfactual information can also cause processing delays. While readers do appear to have concurrent access to counterfactual and real world information when reading, real world knowledge is 'privileged' and is still processed either faster or beforehand (Ferguson & Sanford, 2008; Ferguson, 2012; Ferguson & Jayes, 2017). The delay in anomaly detection is a key finding in relation to how counterfactual contexts are processed, with this study showing that real world expectations have a processing advantage over any counterfactual context. This experiment does present evidence to support a two-step account, due to the delay in negation processing. It also, however, represents evidence suggesting counterfactual information can cause a delay in discourse integration.

Ludtke and Kaup (2006) investigated how context can accelerate the first step of simulating the negated entity. Similar to Glenberg et al.'s (1999) reading time study, Lutdke and Kaup (2006) also found the time taken to read a negated proposition was reduced when it had been primed by mentioning the negated dimension in an acceptable pragmatic context. This facilitation occurred when the negated proposition was presented following a consideration of the relevant dimension within the text (e.g., *she wondered whether the water would be warm... The water was not warm)*. Similar facilitation of negation processing was obtained even if the dimension was only inferred (*She wanted him to look neat…she was not dirty*). A two-step account would not have predicted negation being processed more quickly,

as the first step cannot be avoided, even if it is shortened in this case. Instead, these findings appear to show that context alleviates the need for the first stage.

The authors argued the most common use of negation is to communicate situations that deviate from that which is expected (Givon, 1978). They described negation as having a "pragmatic advantage" when supplied in the context of denial, which subsequently makes up for the higher processing complexity associated with negation. Wason (1965) described this advantage as being due to negation's common use to correct misconceptions. Ludtke and Kaup's (2006) findings show that a processing advantage for negation is also present when expectations are built up through a narrative. They argue that this is not the case with affirmative sentences, more commonly used to assert a concept. Their findings, alternatively, could be explained as being due to the pragmatic constraints placed on a reader. In this case, by introducing a context within which a character is considering multiple possibilities (e.g., *she* ***wondered whether*** *the water would be warm*) a reader's discourse representation is also supplying activation to these different possibilities. When one of these possibilities is denied, readers have already been primed to simulate the true state of affairs causing the licensed use of negation. Instead of explaining negation through multiple distinguished steps, the encoding of negation could be explained as being due to the continuous dynamics of the language system (Tabor & Hutchins, 2000).

In order to account for findings showing negation being processed as quickly as affirmation, Kaup, Yaxley, Madden, Zwaan and Ludtke (2007) updated their experiential two-step theory to include an 'auxiliary representational system". In this system, readers still construct the affirmative equivalent of negated text. Instead of constructing a negated representation afterwards, the affirmative representation is not integrated into discourse but held in an auxiliary representational system. So for the sentence *there was no eagle in the sky*, readers hold a representation of an eagle in the sky in the auxiliary representational system, while the discourse representation features no eagle in the sky, as it is held separately. Readers thus comprehend negation by comparing their discourse representation with the representation in the auxiliary system. Any delay in negation processing within this framework is due to the fact that the system has no context to compare the auxiliary representation to. In null context

sentences, readers cannot compare their discourse model to the negated auxiliary representation, as they have not instantiated a discourse representation. Furthermore, when negation explicitly has a representation within the discourse model (as in Kaup & Zwaan, 2003), readers can more readily compare this with the auxiliary representation. This theory still only really seems to apply for cases where negation is used to signal an absence of an item from context. This is a larger issue with embodied cognition theories of sentence processing, where many sentences cannot be mapped onto experiential simulations (Goldinger, Papesh, Barnhart, Hansen & Hout, 2016). For an example, consider this and the previous two sentences of this chapter and how these would be represented experientially.

In summary, experiential theories of language comprehension (Zwaan & Radvansky, 1998) have inspired new theories that include negation processing within an experiential representation framework. As negation is the denial of something, a direct experiential process does not seem feasible; this led to Kaup and colleagues' (Kaup, 2001; Kaup & Zwaan, 2003; Kaup, Ludtke & Zwaan, 2006) formalizing a two-step process to negation. In this case, negated representations are first simulated experientially (as their affirmative), before being suppressed to create an accurate discourse representation of events. Later findings, however, particularly evidence of negation being processed as quickly as affirmation (Ludtke & Kaup, 2006) led to the introduction of an auxiliary system, which includes multiple representations. This system still dictates that the affirmative is always simulated first. Subsequent theoretical developments take inspiration from the use of multiple representations, but argue for a more dynamic time course.

Dynamic Pragmatic Theory of Negation Comprehension

Much opposition towards two-step situational theory questioned the notion that negation must be processed via a first step, specifically, the simulation and rejection of the negated information. To be clear, the notion that in the processing of negation, this first step (representation of an affirmative equivalent) is unavoidable and obligatory has been rejected within more current theories of negation. Dynamic pragmatic theorists continued to use Wason's (1961, 1965; Wason & Jones, 1963) historical pragmatic account of negation processing, arguing discourse goals and intentions decide how a negated concept is represented. In the cases of unmotivated

negation, therefore, readers have a tendency to generate presupposed information (Grice, 1967), called a pragmatic inference. As previously discussed, negation is considered more informative and processed more quickly when it has been used to deny an expectancy within the context (Strawson, 1952). For instance, when presented with the proposition *the door is not closed* in isolation, readers have to make inferences beyond the evidence given. In this case they have to infer the presupposition that *the door is closed* was a previous possibility. This matches the data provided in experiments above, which do not provide a motivation for negation and find a universal cost of negation (e.g., Just & MacDonald, 1989). Thus the increased time it takes to process negated propositions compared to their affirmative equivalent is caused due to readers having to make this inference to correctly comprehend the text.

It has been argued that the classic studies of negation processing do not meet the contextually dependent constraints that negation requires. Without constraint, a negated proposition is inherently ambiguous and lacks informativeness. Thus a delay in comprehension has been previously found as readers attempt to make a pragmatic inference about why a negation is being used, based on their knowledge of typical language use. Research within a dynamic pragmatic account often provides pragmatic/linguistic signals to the readers during incremental interpretation which constrain readers to expect negation, as occurs in normal language. Thus readers do not need to make any inference, and can instantiate a specific representation for a negated proposition, leading to comprehension times that are equivalent to comprehending affirmative equivalent sentences.

Indeed, Nordmeyer and Frank (2014) have conducted a string of studies that find a facilitatory effect of visual context on negation comprehension in young children using the visual world paradigm. The visual world paradigm measures participants' eye movements as they view a scene while text is delivered aurally. It is now well established that there is a systematic relationship between eye-movements and auditory language processing, with participants' gaze patterns matching their incremental interpretation of language (Altmann & Kamide, 1999; Huettig, Rommers & Meyer, 2011; Shepard, 1967; Tanenhaus, Spivey-Knowlton,

Eberhard & Sedivy, 1995). In Nordmeyer and Frank's study, children were either presented with the visual context of three boys, two of whom were holding *apples*, and another boy that was either holding *nothing* or *presents*. Children were much quicker to follow the instruction "*look at the boy who has no apples"* when the boy had *presents* than when he had *nothing*. It was argued that in the former case, the *presents* act as an alternative, allowing the visual context to meet the pragmatic requirements for the use of efficient negation. Their data provided a strong argument for a link between expectancy and the difficulty of negating a concept. This is based on the fact that negation is a unique pragmatic event, which requires expectancy (a reason for the negation of a concept) to be used felicitously. It is reasoned within a Dynamic Pragmatic account, therefore, that a broader analysis of negated contexts is required in order for negated concepts to be readily instantiated into discourse.

Factors considered within a Dynamic Pragmatic account relate to how a comprehender understands the discourse purpose of a sentence and the semantic properties that affect discourse interpretation. This was investigated in Tian, Breheny and Ferguson's (2010) picture sentence verification experiment. Specifically, they argued that if a sentence is pragmatically licensed, less time is taken to infer the purpose of the negation. Pragmatic licenses are parts of text that reference presupposed information already present within discourse context. Pragmatic licensing causes readers to focus on specific elements of text. This subsequently allows readers to generate inferences about the most important elements within pieces of text. It was argued that some of the inferences generated by pragmatic licensing would include presupposing contrast sets for incoming text. For instance, reading ***it was*** *Jane who will* causes readers to presuppose that Jane either has or has not done something that she should have. In this case, clefting was used, specifically the placing of a pronoun at the beginning of a noun phrase. To test the effect of pragmatic licensing, Tian, et al. provided negative and affirmative versions of sentences that were either clefted (sentence 11) or unclefted (sentence 12).

11. *It was Jane who did (n't) cook the pasta*
12. *Jane did (n't) cook the pasta*

Following these sentences, either a picture of cooked or uncooked pasta was presented. Participants were asked to decide whether the pictorial probe matched the content of the sentence or not. Clefted sentences place a particular constituent of a simple proposition into focus (Collins, 1991). For instance, consider the two phrases; *Mike did iron his shirt*, and *it was Mike who ironed his shirt*. In the case of the latter, *Mike* is immediately thrown into focus. Other examples include *what Mark wanted to buy was a shirt* as the clefted version of *Mark wanted to buy a shirt* with the former immediately placing Mark as the focus of the phrase once again.

Clefts are known as presuppositional triggers (Levinson, 1983), as the pronoun signals the existence of a presupposition beyond the isolated proposition. The researchers argued that the representation with the negated marker would be more readily available. For instance, in sentence 11, the cleft triggers the presupposition that someone *did cook the pasta*, and the negation is reversing the expectancy that it was *Jane*. This means the cleft constrains the potential inferences a reader may make based on the sentence, even without context. In this case clefting would prime the use of negation, as both negation and clefts are functions that rely on presupposition to be used felicitously (Chierchia, 2004). For instance, in sentence 11 the cleft adjusts the expectation of the reader to assume that incoming information will include a contrast based on presupposed information. This means that when readers encounter the negation, it meets their expectancy of a contrast. By generating the inference of upcoming presupposed information beyond what is present within the proposition, clefting should allow readers to understand negated propositions quicker compared to sentences that do not (sentence 12).

It was found that 250ms after a cleft negative (sentence 11); responses were quicker to the negated picture probe (uncooked pasta) than the affirmative. This suggests readers have immediate access to the concept in its negated form before, or at least at the same time as, the affirmative. This would suggest the first step in two- step theory of processing (processing the proposition without a negative marker) does not always occur when a reader encounters negated information. It

was, therefore, suggested that suppression of a negated concept is not always required in order to comprehend negation.

Furthermore, Nieuwland and Kuperberg (2008) investigated the integration of negated sentences via pragmatic licensing, using event-related potentials (ERPs) as a measure of processing linguistic information. They provided participants with negated and affirmative sentences that were inconsistent with world knowledge. They contrasted sentences that provided a pragmatic license for negation (sentence 13 and 14) with sentences without a pragmatic license (sentence 15 and 16). Their pragmatic license was provided through context, as opposed to through clefting in Tian, Breheny and Ferguson's (2010) study.

13. *With proper equipment, scuba diving is not very safe and often good fun*
14. *With proper equipment, scuba diving is very dangerous and often good fun*
15. *Bulletproof vests are not safe and used worldwide for security*
16. *Bulletproof vests are dangerous and used worldwide for security*

Sentence 13 and 14 are anomalous with respect to our world knowledge, both in a negated and affirmative form. They both contain a pragmatic license in the form of "*with proper equipment*", which the dynamic pragmatic account suggests incrementally forms pragmatic expectancies of the sentence. Sentences 15 and 16 are anomalous without pragmatic licensing in the negative and positive form. Nieuwland and Kuperberg used the N400 as a measure of semantic processing difficulty as they are considered to be an immediate, direct response to semantically anomalous content (Kutas & Fedemeier, 2011). This effect has been observed when reading semantically anomalous sentences; such as *I take coffee with cream and dog* (Kutas & Hillyard, 1980; 1984). When an effect of the N400 was found in reaction to one of the sentences in this study, therefore, it was interpreted as the reader being able to immediately interpret the text, as it was rapidly interpreted as anomalous.

A significantly larger N400 was recorded when reading sentence 13 compared to sentence 15. Sentence 13 was pragmatically licensed, indicating participants found that negation to be immediately anomalous, whereas 15 was not pragmatically licensed, and participants did not show evidence of immediately interpreting the negation. An increased N400 was consistently found in the case of

sentences 14 and 16, which are affirmative and are not affected by licensing. This finding was taken to show that in the case of the pragmatically licensed sentence 13, readers immediately represented the negated entity. This allowed readers to correctly assess the truth-value of that statement immediately. Readers therefore, immediately recognized the semantic anomaly in the sentence, evidenced by an increased N400. This was in contrast to non-licensed sentences, where the negation was not immediately represented, as the element of safety had not been focused upon. A larger N400 would not have been present in pragmatically licensed, negated sentences unless participants were immediately accessing the negation. This indicated that a pragmatic license signals to readers that a contrast is to be made, allowing the immediate representation of negated elements.

Applying a two-step account, one would not have expected an increased N400, as the negated entity should not be immediately represented in both items 13 and 15. When negation is used within a clearly acceptable context, it is not more difficult to relate incoming negations with real world knowledge than their affirmative counterparts.

Further research using ERPs has also been extensively used to provide support for Dynamic Pragmatic theory and the notion that negation can be immediately processed. For example, it has been found that the different N400 activation patterns for negative and positive polarity items are preserved when negated. For example, it has been consistently found that the sentences *he felt happy* and *he felt sad* produce differential ERP waveforms (Schacht & Sommer, 2009;Scott, O'Donnell, Leuthold & Sereno, 2009). Jiang, Li, Liu, Luo, Luu and Tucker (2014) found this is preserved when the stimulus sentences used are negated. This means, for example, the stimulus *he does not feel sad* produced the same ERP waveform patterns as the stimulus *he does feel happy*, whilst *he does not feel happy* and *he does feel sad* also produced the same ERP waveform pattern. This preservation of differential activation patterns for words of positive and negative valence can only be explained if negated representations are immediately incorporated into a reader's incremental interpretation of the text. Only Dynamic Pragmatic accounts of negation that can account for these negated sentences being processed within the same timeframe as affirmation.

Hald, Hocking, Vernon, Marshall and Garnham (2013) provide another variable to bring processing of negation into the same timeframe of affirmation, referred to as modality matching. Modality matching refers to the finding from sentence matching experiments that when text switches to a different modality (i.e. which sensory perception the text invokes), there is a cost in processing compared to when a modality is maintained across items (Pecher, Zeelenberg & Barsalou, 2003). For example, verifying the sentence *the leaves rustle*, and then the sentence *a blender can be loud* is less costly in terms of processing than verifying *the leaves rustle* followed by *cranberries can be tart*. This is because both propositions in the former case relate to the auditory modality. This has often been used as a source of support for the notion that sensorimotor systems are used during language comprehension. Similarly, a key tenet of two-step theory is that language comprehension is achieved through experiential representations. While a two-step account argued for the use of embodied simulations, this is not the case within dynamic pragmatic accounts, where many pragmatic variables are included in the representation of negation. If all meaning were built from embodied simulations, as an experiential theory of language predicts, that generates the prediction that multiple utterances that both use a single sense would be comprehended faster than two that switch modality. Maintaining use of one set of modality specific brain systems would logically be easier than using multiple systems. Hald et al., however, present evidence that argues against this embodiment explanation of language and sensorimotor representational accounts of negation.

ERP data from Hald et al. show a similar modulation of the N400 when reading negated sentences that share a modality mismatch, similar to that found in affirmative sentences. They found an increased N400 when a negated sentence was false, but only when the text maintained modality (e.g. *a giraffe is spotted, rice isn't white* compared to *a light bulb is very hot – rice isn't white).* This suggested that negation was processed within the same framework as affirmation, in this case through embodied simulations. This is contrary to the idea suggested in the two-step literature, where it has been argued that negation cannot be processed through the same cognitive mechanisms as affirmation (Kaup, 2001). Furthermore, this means participants were processing negation within the same timeframe as affirmation. The authors suggested modality maintenance (lack of switching) as

another pragmatic factor that, when present, supports and allows negation to be processed through the same mechanisms as affirmation.

Giora (2006) also argued for a discourse-sensitive cognitive architecture that allows negative and positive utterances to be processed within similar time courses. This is supported through extensive linguistic investigation. For instance, there is the finding that the minority of negative usage conveys disagreement, disconfirmation or rejection (Heinemann, 2005) as opposed to the classic notion that negation is almost exclusively used for plausible denial of misconceptions (Givon, 1978; Wason, 1965). Negation can also be used to confirm, endorse or support (consider a surprised *no!* during speech to accept a shocking turn of events). This is the same as affirmation, which can also convey disconfirmation called reversal markers (Taglicht, 2001). While previous theories have considered negation within a narrow framework, often looking at how it signals an absence or denies an expectation, Giora considered the plethora of ways in which negation can be used. Consider Taglicht's investigation of the use of the word *actually*, in the context of *I told them I did A but actually I did B*. While *actually* is an affirmative term, it is being used as a negative marker in this sentence. Here *actually* acts to denote falsity and warning of a change in truth-value towards the following phrase. Furthermore, in the case of *you did A*, *actually you need to do B,* it can be seen how applying stress vocally can cause *actually* to display disagreement. Both of these examples show the use of *actually* as a reversal marker despite it firmly being an affirmative modifier. Considerations such as these have allowed Dynamic Pragmatic theorists to consider negation within a more holistic framework.

Irony is another example where negation is used without the intention of completely reversing the polarity of the statement. Irony is when the meaning of text is opposite/different from that which has been communicated. For example, *you are very smart* when someone has achieved the lowest grade possible (Au-Yeung, Kaakinen, Liversedge & Benson, 2015; Kaakinen, Olkoniemi, Kinnari & Hyona, 2013). Kintsch (1998) argued interpreting irony involves processing the gap between the surface level text and the intended meaning, as this is required to successfully interpret the text. Giora (1995) found stimuli such as sentence 17a were still rated by participants as ironic compared to 17b which creates a much wider, easier to interpret gap.

17. *Max was working hard preparing for his exams. He failed them all.*

a) *Max is exceptionally bright*

b) *Max is not exceptionally bright*

For 17a, even though there is no specific negation, readers need to suppress the meaning of *bright,* in order to accept the ironic interpretation of the text. Readers must interpret a gap between the surface text meaning and the situational model of the text needed to cause an interpretation of the sentence as ironic. These findings indicate that negation does not always reflect a concept being eliminated from readers' discourse representations, sometimes a certain amount of meaning from the negated representation must be retained in order to correctly comprehend language.

Rather than the notion that negation always results in obligatory suppression, the dynamic pragmatic account suggests mitigation and retention of the negated concepts' meaning are equally as likely to occur as suppression. Suppression suggests that no meaning is taken into account when a concept is negated, *we have no toast* means readers have to create a situational discourse model where there is *no toast*, and so the concept has been eliminated. Mitigation refers to a negative marker instructing a comprehender to retain a certain amount of meaning in their discourse representation dependent on a number of constraints (Giora, Balaban, Fein & Alkabets, 2005). For instance, when someone says *dinner was not bad*, they are not immediately suggesting that *bad* be completely suppressed. Instead readers alter their interpretation away from *bad*, but not all the way to a representation of *good*.

Giora, Fein, Aschkenazi and Alkabets-Zlozover (2007) used Hasson and Glucksberg's (2006) stimuli and provided a late context during a self-paced reading task. For instance, compare sentence 8 from Hasson and Glucksberg's study to sentence 18 from Giora and colleagues':

18. *The train to Boston was no rocket. The trip to the city was fast though.*

8. *The train to Boston was a/no rocket.*

It was found that *no rocket* still led to faster reading times of the word *fast,* despite the metaphor implying the opposite of *fast*. The metaphor *no rocket* is unlicensed in

this case, causing increased activation of the negated concept (*fast*). This leads to a priming effect on the negated concept of *fast*. This is an example of negated information influencing word-by-word integration through the incremental build up of pragmatic and contextual expectancies of incoming linguistic information. Clearly context affects the activation levels and access to negated concepts in their negated and affirmative form, a key assumption within pragmatic theories of negation (Anderson, Huette, Matlock & Spivey, 2013; Nieuwland & Kuperberg, 2008).

Giora et al. (2005) presented evidence demonstrating that certain negated sentences prime semantically similar lexical items in the same manner as affirmative sentences when the negated entity is salient. For instance, within a sentential context, it was found that *not sharp* and *sharp* both prime the item *piercing* in a lexical decision task whereas *blunt* does not, despite being a related word. The authors argue this is due to *sharp* being the more salient of the two members of the antonymic pair. When this salient member is negated (*not sharp*), a representation of *sharp* is retained with a reader's discourse representation due to its saliency. In this study, saliency was defined as the more 'prominent' member of the antonymic pair. This shows there are occasions when the concept negated is salient, and therefore more likely to be functionally important to the construction of an accurate discourse representation of the text. This issue is returned to later in this thesis with discussions of markedness.

As has been shown in this subsection, there have been a multitude of findings to show that negation can processed as quickly as affirmation. This has been shown through clefting (Tian et al., 2010), pragmatic licensing (Nieuwland & Kuperberg, 2009; Nordmeyer & Frank, 2013) and considering negation within the context it is used (Giora, 2006). Overall, these findings support Giora's pragmatic hypothesis that the online processing of positive and negative propositions do not have to be markedly different from each other. To allow for occasions where negation can be processed in the same timecourse as affirmation, theories of negation must take into account the discourse intentions and contextual cues provided within negation use. It is only the dynamic pragmatic account that takes into account these global discourse considerations to adequately explain the many purposes of negation.

Relation to Constraint Satisfaction Processing Theory of Language

Many parallels are present between the dynamic pragmatic account of negation and a constraint-based theory of sentence processing (MacDonald, 1994; MacDonald, Pearlmutter & Seidenberg, 1994a, 1994b). Constraint-based theories argue text interpretation is constrained by a large number of sources of linguistic information, each altering the activation level of different interpretations constructed and maintained in parallel. For instance, the use of the focus operator *only* is taken by the reader to indicate that an upcoming linguistic element will be used to contrast with another. It has been found, therefore, that the use of the word *only* facilitates the construction of a discourse representation containing two entities that contrast on a variable (Filik, Paterson & Liversedge, 2009; Paterson, Liversedge & Underwood, 1999;). The sentence *only teenagers allowed a party invited a juggler straightaway* placed the immediate constraint that readers should consider a contrast set of *teenagers* who were not *allowed a party*. Focus operators supply readers with information about incoming text. In this case, *only* causes readers to constrain their expectations to subsequent text to feature a contrast between two sets, and this facilitated the construction of a discourse representation where two sets were contrasted. Similarly, *not* can be seen as signaling to the interpreter that the next concept will appear in a different state from its affirmative version, with the desired interpretation decided, in part, by other pragmatic factors.

For example, in Tian et al's (2010) clefting study, it was seen how the presentation of a cleft (*it was*) provided an advantage in activation of interpretations that involve the presupposition of a negative element. The processing of the negated element in *it was Jane who did not cook the pasta* was faster than in *Jane did not cook the pasta*. This was due to the cleft supplying the reader with a signal that a contrast that relies on presupposition is incoming, and this was confirmed when the negation arrived. Furthermore, Giora (2006) also cites several corpora investigations of negation (e.g., Heinemann, 2005; Stefanowitsch & Gries, 2003) as showing a functional affinity between affirmatives and negatives. This allowed her to reach the conclusion that the processing of negation uses discourse-sensitive cognitive mechanisms to incrementally choose sentence analyses. There are certain parallels here with principles of constraint-satisfaction

theories of sentence interpretation, where constraints on syntactic incremental interpretation have been come from off-line, linguistic and corpus data (Spivey & Tanenhaus, 1998; Spivey-Knowlton & Sedivy, 1995). Specifically, in both cases readers are able to update their expectations and interpretations of text on a word-by-word basis. While constraint-satisfaction does not make this claim about semantic interpretation, there are parallels between the two.

In summary, Dynamic Pragmatic accounts of negation have been formulated by embracing the use of negation in context. Dynamic Pragmatic accounts have rejected the notion that this process must always occur in two steps. Specifically, the idea that an affirmative version of events must be simulated first, before being obligatorily suppressed to create an accurate discourse representation. Instead, it has been found that negation processing can be accelerated by clefting (Tian, Breheny & Ferguson, 2010) and pragmatic or contextual licensing (Giora, 2006; Nieuwland & Kuperberg, 2008). Another pragmatic factor that influences negation processing is the number of possibilities negation can possibly refer to. Negated sentences often do not explicitly denote the intended state in the same way as affirmation. The number of possible alternatives, however, can control the ambiguity of what state the reader is meant to represent. While the previous studies attempt to constrain negation interpretation through context and pragmatic licensing, the next section will detail work that has manipulated the actual concept that is being negated.

Mental Model Theories and Situational Alternative Negation Models

Mental model theories of language processing provide accounts for negation processing that are analogous to that of Dynamic Pragmatic theory. Instead of considering the linguistic nature of negation, however, many mental model studies provide a mechanistic account for the processing of negation. As such, they are not seen as in opposition to Dynamic Pragmatic explanations of negation, but as a potential cognitive companion to the linguistic theory they provide. Mental models are psychological representations of situations, such as those presented by text. When readers represent text, mental model theory stipulates that they simulate the text provided within mental models (Johnson-Laird, 2006). These models encode

elements of the text and the relationships between elements in order to allow readers to reason the intended meaning from text (Fauconnier, 1985, 1994, 1997).

When an utterance demands the interpreter to create a supposition, they are forced to create two separate mental models within this state space. For instance, from the counterfactual utterance *if cats were herbivores*, readers will instantiate one state space for the supposition that cats are herbivores, which is in opposition with reality and another state space for the presupposed facts which match our world knowledge (that cats eat meat - Byrne & Trasso, 1999; Ferguson & Sanford, 2008). In the case of negation, it has been argued that at least two separate mental models are created, the simplest case being the actual state of affairs where the proposition has been negated and a counterfactual space where the concept is in its affirmative state (Mok, Bryant & Feldman, 2004). Importantly, these state spaces are instantiated simultaneously, in parallel, not sequentially, as is the case in two-step accounts of negation.

Huette, Anderson, Matlock and Spivey (2011) attempted to program a model of negation processing. Within their model, all possible situations are mapped onto a three-dimensional landscape. When readers integrate a state into their discourse representation, a certain pattern of activation across that landscape matches each possible state. The processing of language causes propositions to create individual patterns of sensorimotor activation that are indexed to a matching location within this state space. To process language, the specific position in state space which is activated must be indexed to instantiate a correct discourse representation. This conceptualization could certainly frame a two-step account; activation of a negated concept would create a mental space equivalent to its affirmative counterpart, before prompting a change to the actual state of events. In Huette et al.'s successful simulation of experimental data, however, they included the directive that the activation of multiple states is not sequential, instead, both states compete for activation. In this account, both a negative state and an affirmative state are activated, these two compete and activation spreads between themselves and to neighbors in nearby semantic space (Fauconnier & Turner, 2002).

Anderson and colleagues' additional experimental data (Anderson, Huette, Matlock & Spivey, 2011) was generated from a picture verification task. They manipulated the number of possible simulations a proposition should create through the use of context. In one condition, the negation implied one alternative state (e.g., sentence 19a, in this case, the *coin* must be *tails* up), in the other a negation that implied multiple possible states (e.g., 19b, in this case, the *coin* could be anywhere, *the table, the pocket, the hand* etc.).

19. a) *The coin is (not) heads up.*
b) The coin is (not) in the air.

Participants read these negated sentences, and then were presented with pictures that either matched or did not match the sentence. They found that if the negation only has two possibilities, correct congruency judgments were made more quickly. This is due to the tighter contextual constraints on the number of possible outcomes that could be inferred by these types of negation. By constraining the possible situations an utterance can represent to two states, only two possibilities compete, and activation can be guided to the correct index in state space more efficiently. This is compared to multiple possibility negation where many states can be activated within the system creating an unstable processing pattern. Rather than framing their data with the use of a first step (instantiating an affirmative representation of events), the authors argue negated text activates a number of states relative to the level of uncertainty and ambiguity of that negation.

Beltran, Orenes and Santamaria (2008) presented elicitation data that supported a fundamental difference between negations of single and multiple alternative contexts. When participants are required to complete a story, not only are they more likely to give more different responses in the multiple possibility condition (sentence 20), but also they are also more likely to use negation than in the case of single alternative negation (sentence 21).

20. Multiple possibilities - *Juan realized that the information mistakenly stated the car was red. In fact the car was…*

21. Single possibility - *Juan realized that the information*

mistakenly stated the car was big. In fact the car was…

The authors argue this is because the actual state of affairs for these conditions is inaccessible, due to a larger amount of possibilities (e.g., *the car is not red*, there are an abundance of colors it could be). When using of a dimension with a clear antonym (*big-small*), however, readers were much more likely to use this antonym as a completion due to the clear contrast the context had created. With no clear contrast item in the multiple possibility case, participants increased their use of negation on the initial item (*red*). These results provide support for the notion that the meaning of a negated proposition can be made more accessible by the pragmatic context, in this case a lack of alternatives.

Anderson et al. (2013) drew a comparison between their models of resolving the contextual ambiguity of negation with Kawamoto's (1993) neural network model of lexical ambiguity. When a lexical entry activates multiple meanings, the system uses context to inhibit the activation of inappropriate entries (*the color shade was light* eliminates any notion of the weight meaning of *light*). Similarly, the authors argued negation activates multiple state spaces that compete with one another with contextual factors able to inhibit/facilitate activation of possible states. Huette (2016) also provided evidence showing variable interpretation of multiple alternative negations. It was found that participants drew a multitude of possibilities when presented with these ambiguous negations, suggesting participants, without context, were able to create many different interpretations.

Khemlani, Orenes and Johnson-Laird's (2012) theory of negation representation also utilized a mental model design. During negation, they argue that mental models of any possible state are constructed and updated during language comprehension. Given that each possibility is simulated, the more possibilities a negation could refer to, the more mental models needed to be constructed. This context-led approach also posits that the construction of needless models is blocked, therefore, negated core suppositions with only two predicates (e.g. *alive-dead*) only cause the construction of one mental model. A negative core supposition with an ambiguous amount of predicates, however, leads to the creation of many models, which compete for activation, hence a delay in negation processing of negated entities with multiple possible predicates.

Orenes, Beltran and Santamaria (2014) used the same manipulation of alternative states implied by negation in a visual world paradigm. In their case the contexts were explicitly given to participants rather than being implicit as was the case in Anderson, Huette, Matlock and Spivey's (2010) experiment. The auditory context would either present two possibilities (*the figure could be red or green*) or four (*the figure could be red or green or yellow or blue*). Meanwhile, four figures, representing all four possibilities were presented visually in both cases. They were then presented with the target sentence featuring negation (*the figure was not red*). Participants directed a greater proportion of fixations towards the alternative in the binary context at this point of disambiguation than in the multiple alternative conditions (i.e., they looked at the *green* figure more than in the multiple alternative conditions). In the multiple alternative conditions, a higher proportion of fixations were directed at the negated entity (the *red* figure). In the latter case, the negation is relatively uninformative, meaning participants were not able to create a stable discourse representation for the event presented. They chose, therefore, to focus on the negated element to try and obtain meaning from the negation, whereas meaning in the binary condition is derived from the one clear state possible in that context..

Further evidence to support a one-stage account of negation comes from an emerging literature using mouse-tracking data. Mouse tracking looks at the participants' mouse cursor trajectories, through x, y-pixel coordinates. It has been previously shown that mouse cursor trajectories are affected by implicit attitudes whereas the final decision is not (Wojnowicz, Ferguson, Dale & Spivey, 2009). This suggests a moment-to-moment mouse tracking record will be affected by online processing. As negation is suggested to involve competition between different representations, it should be expected that mouse trajectories would reveal effects of the underlying processing of negation. This was the methodological motivation for Dale and Duran's (2011) exploration of negation in context. In this study, the words '*True'* and '*False'* were presented at the top of the screen, with a statement presented in the middle of the screen, one word at a time. The cursor began at the bottom of the screen, in order to measure the mouse trajectory towards the top of the screen.

Dale and Duran (2011) manipulated levels of context with the aim of seeing whether this could constrain a reader's interpretation of negated content, which they

expected to produce simpler mouse trajectories due to lack of underlying competition. The study looked at the trajectory of mouse cursors towards true and false icons on the screen following a negated or affirmative statement presented with differing levels of context. When no context is provided (*elephants are not large*) they found a classic "flip" in response mouse trajectories from heading towards the affirmative representation response (true – *elephants are large*), altering their path towards the negative (false). This finding has previously been suggested to show the extra step required to process negation in propositionalist accounts. Meanwhile, when explained through a pragmatic account, it is due to the inherent ambiguity the proposition carries, as without context the negation is not licensed. This effect was replicated when they introduced a simple preamble text (e.g., *you want to lift an elephant? Elephants are (not) small/large*). When an enhanced pragmatic context was presented before the sentence (e.g., "*you want to lift an elephant?" The mother said to her child, "but elephants are (not) heavy/light"*), the "flip" was not apparent in mouse trajectories. The authors argue that while the first use of context creates plausible denial and should constrain readers to expect a negated contrast, the latter supplies a longer context more commonly used in negation experiments (e.g., Nieuwland & Kuperberg, 2008). This more deeply embedded context allowed the reader more time to constrain their expectations of the text. Thus, the context affected the mental processes of how readers interpreted a negated proposition, allowing a more rapid instantiation of a negated representation.

Contrary to these findings, Orenes, Moxey, Scheepers and Santamaria (2016) actually found that, even in the presence of embedded context, negation was always slower to process than affirmation. In this case, they used the visual world paradigm, with two opposite images on the screen (e.g. a man with lots of money and a man with very little money) and participants listened to a vignette that finished with a sentence featuring a negative/affirmative sentence (e.g. *her dad was rich/not poor).* They found that when the vignette gave a context that was consistent with the negation, as opposed to inconsistent or neutral, participants were quicker to look at the correct image, but this was still slower than in the affirmative condition. Clearly, research is still needed to investigate the level of context that influences negation and

the level of detail required in order to make negation be processed as quickly as affirmation.

Huette, Anderson, Matlock and Spivey (2013) further detailed their one-stage model of negation using a mouse trajectory experiment. This model classified negation as a contextual modifier which signals the next word will be of diffuse meaning to its standard definition (e.g. the negated – *the juice is not on the table is* of much more diffuse meaning than *the juice is on the table*). Readers are able to accommodate the alternative meaning more readily if there is only a binary alternative due to a lack of competition between different mental models. Multiple alternative locations create more diffuse mental models in an attempt to account for all the different possibilities. Their subsequent data served as a replication of their previous manipulation of alternative states (Anderson, Huette, Matlock & Spivey, 2011), but with the use of mouse tracking, which further supports their model. Mouse trajectories were relatively straight during affirmative trials and yielded significantly shorter reactions times than negative trials. In the case of negative trials with multiple alternative meanings, initial acceleration of the mouse was slower, indicating an effect of competition between different representations, followed by a greater acceleration towards the end of their response time. The final acceleration is taken to show an accumulation of activation towards the correct representation. These results, as a collective, appear to support mental model theories where representations compete for activation, incrementally, word-by-word.

The theoretical position taken in this thesis is that readers reach an interpretation of text based on probabilistic constraints available from the linguistic input. As such, theories of negation must take into account how reading processes and pragmatic considerations influence the comprehension of negation. Only Dynamic Pragmatic theory and mental model theories of negation, as discussed, take into account these considerations. This thesis, therefore, aims to add to the literature on negation by considering how linguistic variables can affect negation interpretation and its time course.

In summary, within one-stage mental model theories of negation, negation is a contextual modifier as it suggests the next item will be of diffuse meaning compared

to in its affirmative state. Rather than negation indicating the absence of a negated concept, the negation is used to suggest diffuse possibilities are incoming from the text.

Boundedness and Antonymic Negation

Mental model theory and dynamic pragmatic accounts of negation both consider the specific prediction that a negated entity does not necessarily create a delay in processing. Instead, negated entities can be instantiated immediately when only one possible representation could be inferred from the text. This will be investigated through the variable of *antonym boundedness*, a distinct linguistic operator in the processing of antonymic negation. The main research question relates to whether the linguistic notion of boundedness influences the instantiation of negated representations.

Boundedness refers to the configuration of the dimension upon which antonyms are set (Paradis, 2001); see Figure 1 for a graphic representation of this variable. Antonyms are pair-wise lexical items whose representations are the semantic opposite of each other (e.g., *dead-alive, bad-good*). Antonyms differ in one specific aspect of meaning, the polarity of the concept they denote (Cruse, 1986; Willners, 2001). For instance, *tall* and *short* differ in describing the positive and negative extremities of the same concept - height. Within the linguistic literature (Kennedy & McNally, 2005; Paradis, 2005; Paradis & Willners, 2006) antonymic pairs that denote differing states have been split into one of two categorizations. The pair can express a state within a range on a scale such as *wide* and *narrow.* In between these two points of polarity, many possible states or options can exist, in this case, varying degrees of width. These are referred to as **unbounded** antonyms. For instance, we can describe a road as *narrower* or *wider* in comparison to another, with many possible states existing on the scale of width. The alternative is **bounded** antonymic pairs, which express two definite opposites, such as *alive* or *dead*. The two antonyms are mutually exhaustive, as there are no other possible states in between. Furthermore, the two states are mutually exclusive, as one must be one or the other, someone cannot simultaneously be *alive* and *dead.*

In this section aspects of boundedness are described, followed by a discussion of how boundedness is already being used within psycholinguistics to understand how we comprehend negation. This thesis will, ultimately, report a series of experiments that will test whether boundedness is a linguistic operator that is taken into account online during language comprehension.

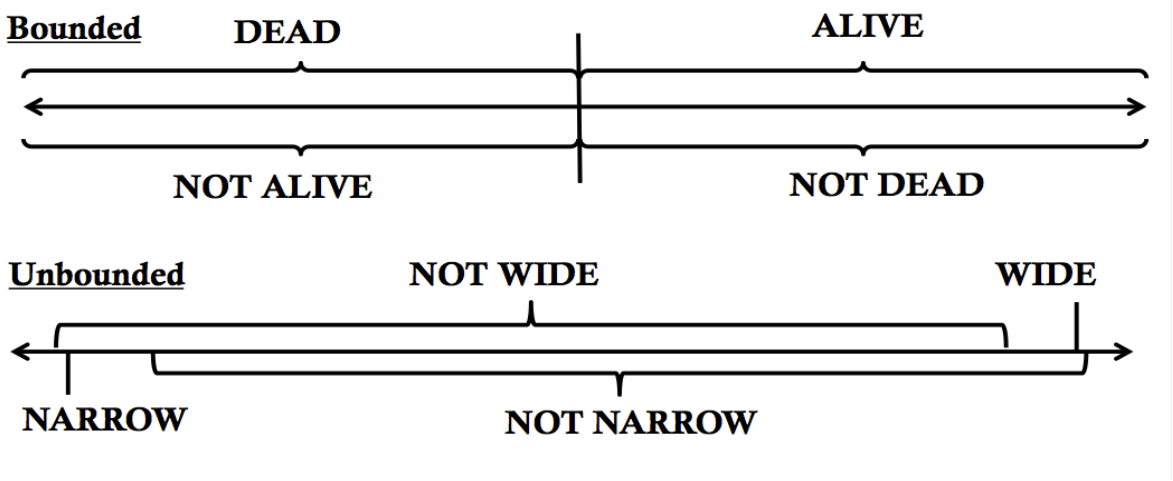

Figure 1.1. Graphical representation of a bounded and unbounded dimension and the applicability of their respective negated items.

Antonyms are an important grouping variable in the acquisition of language (Jones & Murphy, 2005). A word's antonym is one of its most readily associated words (Abwender, Swan, Bowerman & Connolly, 2001); sixty percent of adjectives have antonyms as headwords in dictionaries (Paradis & Willners, 2007). One key difference between bounded and unbounded concepts relates to how the two antonyms describe opposite states. As bounded states denote absolute, categorical states; they cannot plausibly combine with gradable adverbs, like *a bit dead* or *really dead*. Due to bounded states being mutually exclusive, adverbs that denote comparability cannot be use to describe them. Instead, absolute adverbs must be used like *absolutely* or *completely*. The two polar states in bounded concepts are the only two states. Furthermore, opposite states in bounded statements are mutually exclusive, but this is not the case with unbounded statements. Sentence 23 is, therefore, acceptable during language production, whereas sentence 22 is not (Paradis, 1997).

20. *She is neither alive nor dead*
21. *The road is neither wide nor narrow*

Unbounded states contain a theoretically infinite number of states within their semantic configuration. As such, unbounded scales do not actually possess expressible poles when expressed in normal language. For this reason, phrases such as *absolutely/completely wide* are not felicitous within normal language. Gradable adverbs, such as *a bit* or *really* combine with unbounded states to modify the degree of the state being expressed.

Linguists researching how people form their conceptualizations of the word have claimed that unbounded gradable items possess a different semantic configuration when compared to bounded items. In the case of the negative - *not large* will not necessarily be interpreted as its antonym: *small*. If we take a bounded example, on the other hand, it can be seen that the negative - *not open* would be interpreted as it's opposite: *closed* (Kennedy & McNally, 2005). Kennedy and McNally (1999) state that the abstract cognitive representations of measurement for unbounded items are dynamically defined by the context within which they appear. For example, the judgments of concepts such as height or weight depend on contextual comparatives (*Michael Jordan is tall* is true in the context of normal people but not when compared to other basketball players). Even in the case of the extreme *tallest or hottest* the exemplar can still only be placed on a scale in comparison to other objects. This is compared to bounded items where there is no context dependency when representing bounded states. *The sailor is alive* does not relate to a standard but, rather, to a fixed state which does not require a comparative scale of *living*. From this reasoning, it is clear that there is a key distinction between bounded and unbounded concepts. Specifically, that bounded concepts possess two states that are mutually exhaustive of the number of possible states that concept.

Paradis and Willners' (2006) study found that the boundedness of a negated entity affects readers' interpretation of that negation. They measured participants' reaction times and acceptability ratings of bounded and unbounded negation. For example, having been presented with the sentence *the man in the bar was not short/tall;* they were asked *how big was the man?* The rating scale used to answer this question subsequently gave two polar examples, such as in the case of the adjective pair *tall/short*; the polar examples were *pixie* and *giant*. Participants answered the

question by selecting a position on an 11-point scale between the two polar examples to describe the antecedent. They found that negated bounded adjectives were rated as being very similar to their antonym. *Not alive* is considered to be the same as the item *dead.* This is in contrast to unbounded negations that were rated as being significantly different from their antonym. Items such as *not wide* would receive a relatively lower similarity rating to the item *narrow.* Furthermore, negated unbounded adjectives received more variable similarity ratings than negated bounded adjectives. Unbounded negations were, therefore, considered to have the capability to occupy many possible states along the dimension being denoted. Bounded negation, in comparison, can only refer to one possible state, the antonym of the lexical item negated.

These findings support the notion that there are functional constraints on processing and interpretation of negated concepts. In the case of the Paradis and Willners (2006) study, it can be seen how boundedness constrains the number of possible interpretations of a negation. In the case of a bounded negation, there is only one state possible, due to the semantic configuration of a bounded concept. The negation, therefore, can only be interpreted as the negated items affirmative antonym (for example, *not dead = alive*). This process is similar to classic accounts of negation, where the negative operator just reverses the polarity of the meaning of the negated concept completely in order to interpret it correctly. In the case of an unbounded negation, the semantic configuration of the negated concept provides much looser constraints over the number of available alternatives. As an unbounded concept has three or more possible states, when an unbounded antonym is negated, at least two other states could be inferred. This makes unbounded negation much more ambiguous as, in isolation, we cannot know which specific state should be inferred, as there are at least two alternatives. When told someone is *not late,* we can infer the person is either *early,* the antonym of the negated item, or we can infer another state of *on time*, as the concept of punctuality is unbounded. From this, we can generate the prediction that bounded negation should be processed much more efficiently, as there is only one alternative generated by that negation, compared to multiple alternatives in unbounded negation.

Dynamic pragmatic accounts of negation suggest that many other constraints can cause negation to be interpreted more quickly. For instance, Glenberg et al.'s (1999) use of supportive context causes readers to consider a dimension, constraining them to expect a negated comparison. Also consider Tian et al.'s (2010) use of clefting to constrain a reader's expectations to expect a comparison, as the cleft highlights a certain part of the proposition. This thesis will propose that boundedness, the semantic configuration of negated concepts, affects on-line sentence comprehension, due to the differential constraint it applies to the interpretation of negation.

Fraenkel and Schul (2008) found that participants do see negated bounded concepts as synonymous with their affirmative antonym. They defined unbounded concepts as **contraries** – two adjectives that cannot be simultaneously true, but may be simultaneously false – e.g., *the coffee* cannot be *hot* and *cold*, but it can be neither. This means that the negation of an unbounded concept instantiates an interpretation somewhere on the continuum, away from either pole on a rating scale. Unlike the negation of a bounded concept, which forces a dichotomous interpretation, leading to more extreme ratings (towards the poles). These were termed **contradictory** negations, where two contradictory negations can be true or false. One cannot be *alive* and *dead,* nor can they be neither. In their sentence-rating study, they replicated Paradis and Willners' (2006) finding that bounded negations were rated as being more similar to their antonym than unbounded negation. For example, *not dead* was considered to be more similar to *alive* than *not bad* was to *good*.

Furthermore, Fraenkel and Schul (2008) suggest that offline negation interpretation is affected by the markedness of the negated term. Markedness refers to how frequent each member of an antonym pair is (e.g. in a neutral context, asking someone *how old someone is* has no marked intention, whereas *how young someone is* carried the marked assertion that you think that person is *young)*. An unmarked member is usually the positive member of the antonymic pair and is more frequently used in language (Hartmann & Stork, 1972). Unmarked members are considered more neutral; with offline ratings suggesting questions such as *how tall was the ladder?* bear no implication on the height of the ladder and provides no constraint, as *tall* is usual and not marked. This is compared to *how short is the*

ladder? which constrains readers to a pragmatic inference that the ladder is *shorter* than usual, unlike in the unmarked case (Battistella, 1996). In this case the unmarked member would be *tall* and the marked would be *short*. Further evidence comes from Giora et al. (2005), who, recall, found readers negated 'prominent' members more quickly than less prominent members.

Fraenkel and Schul presented off-line evidence that showed that when a marked member was negated, readers interpreted it as being synonymous with its antonym (e.g. *not short* was rated as meaning *tall*). Readers rated unmarked negations as being less similar to their antonym than unmarked negations (e.g. *not tall* was not necessarily interpreted as *short).* They argued marked members are often the negative polar antonym. Furthermore, they argued negative polarity items are often used to denote an absence of the positive item (*short* denotes a lack of *tall, bad* denotes a lack of *good*). As the function of negative items is to denote an absence of positive items, Fraenkel and Schul argued marked members possess a narrower range of meaning than unmarked members. Thus, when marked members are negated, readers will interpret a marked negation less ambiguously, and interpret it as its antonym.

Marked items possess, therefore, a narrower range of meanings. Thus, their negation has been suggested to possess a narrower range of meanings, allowing it to apply more constraint than unmarked negation. When a speaker negates an unmarked member, such as with the statement *the food was not good*; they are framing their statement to evaluate the concept as informatively as possible. *The food* is, therefore, being referred to as *bad,* as there are the negation possesses a smaller range of meanings. But if we consider the phrase *the food was not bad*, we can see how this would not necessarily mean the *food was good*. The negation of the marked member (*bad*) possesses a larger range of meanings than in the previous example.

Linguists have suggested that unmarked members are neutral and their negation is less structurally ambiguous as they often possess the presence of a feature, whereas the negative member is often defined by its lack of the positive member (Haspelmath, 2006). For instance, to be *tall* is to possess the feature of

having lots of height. In comparison, being *short* is defined the by the lack of the marked members' properties, i.e. the lack the presence of *tall*, making it not marked by the distinctive feature of height. When negating a marked member, therefore, readers will infer that the speaker is negating the distinctive feature that makes that member marked. This causes a general "positivity bias" in how we commonly speak, as it carries a richer, less ambiguous evaluation of events (Honda & Matsuka, 2014). When we negate a marked member, e.g., *the food was not bad*; we are not negating a distinctive feature but negating the lack of that feature, which generates more possibilities. This negation is more ambiguous, as it does not target a specific feature of the concept; this causes the reader to generate more possible states in their discourse representation. Practically, Fraenkel and Schul's findings suggest that *not good* resembles *bad* to a higher degree than *not bad* resembles *good.* These findings further suggest that the semantic configuration of two antonyms' concept affects how negation is processed. Not only does boundedness affect the number of possible representations that can be instantiated by negation, but whether it is the negative or positive antonym being negated is also a variable of interest.

Mayo, Schul and Burnstein (2004) also report a functional difference between the processing of negated bounded and unbounded information in Hebrew, a language with no prefixal negation (e.g. *unadventurous*). Their time congruency judgment task had a subject described by what they defined as a bipolar or unipolar adjective, e.g., *John is (not) a tidy/adventurous person*, respectively. Bipolar adjectives clearly have a single opposite (*tidy-messy*), whilst unipolar adjectives do not (*adventurous*). Participants were then presented with statements and were asked whether they were congruent with the description or not, with the congruency determined by whether the previous statement was affirmative or negative. For example, sentence 24 is congruent with the affirmative of *tidy* and incongruent with the negative- *not tidy*, while the opposite is true of sentence 25.

22. *John's clothes were folded neatly in the corner* (tidy congruent/not tidy incongruent)
23. *John forgets where he left his keys* (not tidy congruent/tidy incongruent)

Negated bipolar adjective descriptions yielded significantly faster reaction times to congruent statements than incongruent (e.g., *John is not tidy - John forgets where he left his keys*). Negated unipolar adjective descriptions yielded significantly faster judgment times to incongruent sentence probes (e.g., *John is not romantic – John bought his girlfriend flowers*). This suggests that when assessing congruency statements to negated bipolar adjective descriptions, readers can immediately instantiate a negated representation into their discourse model. This is not the case with unipolar adjective descriptions, however, where no single representation can be immediately instantiated. In the case of a bipolar negation, only one other interpretation can be simulated (Kaup & Zwaan, 2003) or mental model can be constructed (Fauconnier, 1985).

Mayo et al.'s (2004) finding that affirmative sentence judgments were faster than unipolar negative judgments can be accommodated by propositional and situational two-step accounts. Using such an account, we could describe the delay in comprehending negated concepts as due to the extra mental processes negation entails. First, the concept without negation is represented, followed by the suppression of that affirmative representation to fully interpret the negation. This is a process not present in affirmative statements; meaning comprehension of negative statements is slower than their affirmative counterparts. The separate priming patterns of negated bipolar and unipolar concepts for congruency judgment reaction times cannot be accounted for by these accounts. Instead, these priming patterns are interpreted as showing that the additional mental process of suppression does not always occur. In the case of bipolar negation, there is a single representation that can clearly be inferred. Thus, this representation is instantiated immediately. This is not the case when negating unipolar concepts, where there are multiple possible representations that could be inferred. This means there are multiple states that are represented, creating a delay in the processing of unipolar/unbounded negation.

Mayo et al. (2004) explain these findings in terms of the schema upon which negated propositions are encoded. In the bipolar case of *John is not alive*, the concept is dichotomous, there is only one possible representation for that negation. This means the schema chosen is not *alive*, but *dead*, the only remaining option. This single representation is immediately dominant and immediately accessible, shown

in the faster reaction times to sentences that are congruent with bipolar negation. This cannot be explained by suppression accounts of negation, such as through mental encapsulation (Clark & Chase, 1972) or the initial, obligatory representation of an affirmative representation that needs suppression (Kaup, 2003). Both these accounts posit that the processing of negation must always be slower than an affirmative equivalent. When the negation can only infer one representation, however, it is found that this not the case.

In the case of the unipolar phrase *John is not adventurous*; the core preposition does not have a natural oppositional representation that can be immediately instantiated. The authors argue that, in this case, the schema chosen to try and represent the negation is *adventurous*. Unlike the bipolar example where one representation can immediately be represented, the negation is more ambiguous, and encourages multiple representations to be considered. This means readers cannot access the negative statement as quickly as in the bipolar case. This is evidenced by Mayo et al.'s finding of faster judgment times to incongruent sentence probes to negated unipolar adjective descriptions than affirmative descriptions. Mayo et al's study is a good example of how the number of alternative simulations created by negation impacts how readers process that negation. In this case, the negation of a concept with clear oppositional representation (*tidy-messy*) is processed much more quickly than a concept with no opposing item. As the latter negation is ambiguous, it encourages multiple representations to be considered, slowing the successful interpretation of that negation.

Boundedness and its effect on negation processing can easily be integrated with one-stage models of negation processing, specifically, dynamic pragmatic and mental model theory. The boundedness hypothesis proposes that the possibilities of meaning can also be based on the semantic configuration of a negated concept (e.g., *dead/alive* is a categorical concept, *long/short* represent a scalar representation of a modified noun; Paradis, 2005). To suggest *a patient is not dead and not alive* would cause the reader to instantiate a representation of the only two arguments in that concept's domain, two state spaces that are both mutually exclusive and mutually exhaustive. This is compared to unbounded concepts, such as suggesting *the employee is not late and not early*. In instantiating this representation, the two state

spaces can co-exist as a third possibility exists within this domain – *the employee must have been on time/punctual*.

In summary, dynamic pragmatic theory has become more prominent in recent years, mirroring the move towards constraint satisfaction accounts of sentence processing. The way negation constrains a reader's incremental interpretation depends heavily on the number of viable alternatives. In the case of boundedness, it can be seen how negated bounded concepts can only lead to the assertion of one entity (*not dead* can only mean *alive*). This constrains a reader's interpretation more than in the case of unbounded concepts, where the negation can lead to at least two possible states, creating greater ambiguity (if *the employee is not early and not late* the reader must infer that he was *on time*). This is the same when it comes to multiple and single alternative negations, with multiple alternative negations creating greater ambiguity than single alternative negations (Anderson, Huette, Matlock & Spivey, 2013; Orenes, Beltran & Santamaria, 2008, 2014;). To accurately test the predictions this would create about how readers interpret bounded and unbounded concepts online methodologies such as eye movements would be ideal. As eye movements reveal the underlying online processes of reading (Liversedge & Findlay, 2000), they provide unimpeded temporal and spatial measures of how readers process text. The next section will explain some typical eye movement behavior and their utility in understanding underlying semantic analysis and discourse processing.

Eye Movements and Reading

Eye tracking as a research method has widely been accepted as a useful means of insight into cognitive processing over the last 40 years (Rayner, 1998; 2009; Liversedge & Findlay, 2000). Within eye movement and reading studies, eye fixation locations and durations are recorded as an index of how participants read through text. Using eye movements we can observe natural reading behaviour (which cannot be accomplished with other methodologies such as self-paced reading time or lexical decision tasks) and explore the impact of various variables that can be manipulated in the text.

In this section a brief overview will be provided of typical eye movement behaviour and the main factors that can effect eye movements with focus, in particular, on the findings from research investigating semantic processing as that area is very relevant to this thesis topic. The first section will detail some landmark findings regarding lexical access (the speed at which readers identify and match a word in text to its matching referent within their mental lexicon). These are briefly discussed in order to convey that eye movements during reading reflect cognitive processing of text and the timing of fixations during reading are not just reflective of sampling visual information. The second section introduces examples of the use of eye movements as a methodology to investigate semantic processing of text, an area of more relevance to this thesis. Finally, eye movements and reading is compared to other psychological research methods, in order to convey the advantage of using eye movements to study the processing of negation. Primarily, this is because eye movements provide an uninhibited measure of how readers process text online as they read.

Typical Eye Movement Phenomena in Reading

Typically during reading, our eyes do not move smoothly over lines of text. Instead eye movements are made up of fixations, where the eye is steady and saccades, the movement between fixations. When the eye is steady during a fixation, the reader can visually encode linguistic information from text. During saccades, sensitivity to visual input is suppressed due to the high velocity of the eye movements, such that only a blur would be perceived (*saccadic suppression*, Uttal & Smith, 1968). It has been argued that the presented visual input (i.e., the words being read) acts as a mask to reduce any blurring effect (Chekaluk & Llewellyn, 1990). In typical adult populations, fixations last 225-250ms during silent reading (Rayner, 1984) and saccades last around 30ms dependent on the distance moved (Rayner, 1978). It is the acuity limitations of the eye that necessitate these patterns of eye movement behavior. The central 2° of vision has the highest acuity (fovea), with acuity falling dramatically as a function of distance from this region with the parafovea extending approximately 5° outwards, followed by the periphery where acuity is very poor. It is the placement of the fovea onto parts of the stimulus we wish to sample that drives human eye movement behavior (Rayner, 1998; 2009).

There has been a vast amount of eye movement and reading research over the years and it is now well established that a wide number of variables have a stable and reliable effect on eye movements. So much so that the coupling of the variability in eye movement measures to cognitive processing during reading is now widely accepted. Extremely robust effects of word properties such as frequency, length and predictability on lexical identification are reflected in eye movement measures. Fixation duration is heavily influenced by the frequency of a lexical item's usage within the language, with high frequency words fixated for less time (Inhoff & Rayner, 1986; Rayner & Duffy; 1988), or skipped altogether (Henderson & Ferreira, 1993; Rayner & Fischer, 1996). This suggests that eye movements are made according to the cognitive process of lexical identification (Reichle, Rayner & Pollatsek, 1999; 2003). The same interplay between fixation durations and word length can also be found, with short words yielding shorter fixation durations and an increased likelihood of being skipped (Brysbaert & Vitu, 1998; Rayner, 1979). Finally, highly predictable words are much more likely to be skipped than low predictability words (Drieghe, Rayner & Pollatsek, 2005; Ehrlich & Rayner, 1981). These findings are clear illustrations of how the lexical, orthographic and semantic characteristics of words and their effect on cognitive processing are clearly reflected in our eye movement behavior. Essentially the more 'difficult' an item, whether it be a longer word, a less frequent word or a less predictable word, the longer a reader will spend on that item to process it. Many more factors affect fixation duration on words such as age of acquisition, lexical ambiguity and lexical complexity (see Duffy, Morris & Rayner, 1988; Juhasz & Rayner, 2006; Rayner & Duffy, 1986).

Clearly, measures of eye movements do not just reveal latencies of visual information intake, as they are also a reflection of the cognitive processing of that visual information (Liversedge & Findlay, 2000). Further evidence suggesting a coupling of eye movements to cognitive processes outside of visual processing comes from research using disappearing text paradigms. In these studies, it has been found that when a word has been fixated for at least 50-60ms, before being replaced with masking characters or a blank space (using an eye contingent change paradigm McConkie & Rayner, 1975; Rayner, 1975), eye movement behavior continues quite normally (Rayner, Inhoff, Morrison, Slowiaczek & Bertera, 1981; Rayner, Liversedge

& White, 2006). Furthermore, fixation durations were still modulated by word frequency (Rayner, Liversedge, White & Vergilino-Perez, 2003) when reading using this paradigm. This clearly shows that eye movement patterns are directly related to the cognitive processing of the visual input, not just in terms of sampling that visual input. Lexical identification and higher order reading processes cannot occur within 50-60ms (fixations are frequently as long as 220-250ms). Instead, text comprehension processes can be initiated within 50-60ms and have a lasting effect on cognitive processes (i.e., lexical identification), and therefore on eye movement behavior.

To summarize, eye movements are informative in revealing moment-to-moment processing that occurs during reading. In the studies of word recognition used above, it is clear how manipulations of single lexical items have revealed underlying mechanisms of typical lexical processing. There are a number of factors that have an impact on when and where we move our eyes, but for this thesis we wish to focus on the effect of semantics. For a review on a large number of factors that can effect when and where we move our eyes, see Rayner (1998, 2009). The next section will show how syntactic and semantic manipulations have yielded an important understanding of how readers processed this higher-level linguistic information.

Eye Movements and Semantic Processing

Considering how well studied some variables are in the eye movement and reading literature, there is large gap in eye movement research exploring the impact of semantic factors on reading. Negation is an area of experimental psycholinguistics where measures of online processing are largely absent (one exception being the aforementioned Ferguson et al., 2008 study of negation and counterfactuals, also see: Nieuwland & Kuperberg, 2008, for instance, for the use of ERPs, and Dale & Duran, 2011 for the use of mouse tracking). In this thesis, a series of experiments address this gap within the psycholinguistic literature. As negation and boundedness are the variables of manipulation, these experiments consider how higher level (in comparison to lexical processing) effects of semantic processing affect reading, as an index of semantic integration of text with their discourse representation.

Semantic and pragmatic anomalies affect eye movement measures during reading; specifically, longer reading times and a, sometimes gradual, increase in regressive eye movements (Braze, Shankweiler, Ni & Palumbo, 2002; Ni, Fodor, Crain & Shankweiler, 1998). Regressive eye movements back into earlier parts of the text are made to allow for reanalysis of previous content, as readers understand there was a difficulty with their initial interpretation of the text. Importantly, these effects tend to affect 'later' measures of reading times which include measures that show the impact of re-reading of the text, such as go-past times (the sum of all fixations on a region before going past that region), total reading time and number of regressions (right-to-left eye movements in English). Earlier measures of reading are related to word recognition (Clifton, Staub & Rayner, 2007); these include measures such as first fixation duration (first single fixation on a words) and gaze duration (amount of time spent fixating a word before a saccade away from that word is made).

In this section, two studies of plausibility (how probable a word fits with prior context) and garden-path (syntactic misanalysis of sentences) effects are presented, in order to display how eye movement research has been used to investigate high order linguistic effects. This literature is vast and expanding, it is outside of the scope of this thesis to review the entire sum of work in this area (see Clifton & Staub, 2011 and Warren, 2011 for reviews) this section is designed to provide relevant examples within the context of this thesis.

Semantic interpretation and discourse integration manifest in eye movement measures. These measures include regressions (right-to-left eye movements in English) back to earlier regions of the text when their first analysis has been shown to be incorrect, which occurs in cases such as garden path sentences (Rayner, Carlson & Frazier, 1983; Rayner & Frazier, 1987). In these cases, when participants read a sentence such as *the horse raced past the barn fell*, readers syntactically parsed this as a basic noun phrase (*the horse raced*) plus an active intransitive verb (*past the barn*). This analysis was shown to be incorrect when readers fixated on the word *fell*. At this point, fixation durations increased on the disambiguating word. Furthermore, readers regressed back into the text to disambiguate that *raced past the barn* was in fact a reduced relative clause. So *fell* must be attached to the *horse*,

which had been *raced past the barn*. Clearly, how readers syntactically analyze sentences affects how they move through text, with eye movement patterns providing a useful index of how readers accommodate syntactic misanalysis.

As a result, researchers have used measures such as go-past time to investigate when anomalous content is detected and affects instantiating a correct discourse representation (Liversedge, Paterson & Pickering, 1998). Go-past time reflects the total time taken from first fixating a word to moving forward to the next word, including all rereading of earlier parts. Regressions back into the text and total time spent reading a section of text reflect time spent reanalyzing text, indicating how difficult sections of text are to instantiate into a discourse representation. The studies above have shown that when a disambiguating word is immediately anomalous, it will cause immediate syntactic reanalysis. Readers are more likely to immediately regress and spend longer rereading text. This leads to increased regression rates, as readers move back in the text, longer go-past times, due to the time spent rereading previous parts of the text, and increased total reading time on any region that is reread. As stated at the beginning of this chapter, the eye movement experiments within this thesis will investigate the level of processing disruption created by multiple bounded and unbounded states. Similarly to how these studies investigated how readers recover from syntactic misanalysis, the experiments in this thesis investigate how readers recover from being presented with a different antonymic state to the one they have already read.

Violations of plausibility, how reasonable or probable an event is, have also been used to show that an inability to integrate semantic information into a coherent discourse representation causes severe disruption to reading. Specifically, readers immediately detect words that cannot be thematically assigned to the context, shown by longer gaze durations and go-past reading times on the word *carrots* in sentence 26 (Ferguson & Jayes, 2017; Joseph, Liversedge, Blythe, White, Gathercole & Rayner, 2008; Rayner et al., 2004). When the word was only implausible (sentence 27), however, disruption to reading was delayed until further into the text after the implausible word (*carrots*). These studies are critical in showing how readers update their incremental semantic interpretation on a word-by-word basis, as readers detected plausibility violations as they occur. This is only

possible if readers were updating on a word-by-word basis, as opposed to carrying out semantic integration processes at the end of sentences/propositions. In summary, it is possible to use eye movements to detect how readers are semantically interpreting and syntactically parsing text by deliberately leading the reader to either misinterpret or create an interpretation that it is not possible to semantically integrate. Of particular relevance to this thesis, is the gradable effect of plausibility, with anomalous events causing more disruption than implausible events. Similarly, this thesis will look to make a distinction over how implausible multiple bounded and unbounded states can be within a single situational context.

20. John used a pump to inflate the large carrots for dinner.

21. John used an axe to chop the large carrots for dinner.

Further research into plausibility has found that context can buffer against semantic implausibility, for example Warren, McConnell and Rayner (2008) have reduced the difficulty of comprehending implausible events in early eye movement measures. They made a sentence such as *inflate the large carrots* plausible by providing a context of the *carrot* being a *parade balloon*. Similarly, Ferguson and Sanford (2008) made the implausible event plausible with a counterfactual qualifier (*if cats were vegetarian … they would eat carrots*). Any facilitation of the context manifested in late measures of reading, such as total reading time and regression rates in areas after the anomaly, as there was a delay in accessing the counterfactual information along with real world knowledge. Both of the above measures are considered to correspond to later measures of the processing of a word (Staub, 2011), while earlier measures, such as first fixation duration and first pass reading also increase as a function of the strength of implausibility (Warren & McConnell, 2007). This shows a relatively late effect of context in sentence comprehension. Filik (2008; Filik & Leuthold, 2013) was also able to eliminate late reading effects using rich fictional contexts (having *the Incredible Hulk pick up a lorry* rather than an normal man) suggesting that readers are able to create state spaces where real world expectancies are regularly violated during the formation of a discourse representation

The current review of the eye movement and reading literature has detailed examples of research into higher-level syntactic and semantic variables during reading. The fact that these effects of higher level semantic processing are well documented in the eye movement literature makes for a compelling case for the use of eye tracking as a methodology in investigating negation and boundedness. The studies within this thesis attempt to investigate the nature of the representations that readers instantiate when presented with negation and bounded/unbounded items. From the psycholinguistic literature previously discussed, it is reasonable to expect that any delays in negation processing should be detected within an eye movement record. Furthermore, it is possible to test assertions of boundedness. If notions of boundedness (Fraenkel & Schul, 2008; Kennedy & McNally, 2005; Paradis & Willners, 2006) affect online instantiation of representations, as well ultimate interpretations, as shown in offline rating studies, then eye movement behavior during the reading of these negations should reveal effects of how they are processed. For instance, if bounded concepts are mutually exhaustive, and this is considered during semantic processing of text, then a situational model featuring a *patient* who is *not dead* and *not alive* should cause serious disruption to reading, similar to that seen in anomalous sentence stimuli. Within a comparable unbounded example, such as that of a *road* that is *not wide* and *not narrow*, however, we would not expect such serious disruption, as readers can integrate these two representations. Importantly, the literature of eye movements and semantic literature provides a rich context to motivate research into representations of boundedness during reading.

As detailed, one of the most important effects concerning the ease of difficulty of lexical processing and semantic integration of a word is the amount of time spent on that word (Rayner, 1998; 2009). Eye tracking provides an explicit measure of this visual behavior online, and has yielded clear semantic anomaly effects (e.g., Ferguson et al., 2008; Rayner et al., 2004). These effects include bigger violations of syntactic rules and plausibility exhibit earlier disruption in the form of longer fixations and regressions paths from the point of the violation. Subtler effects tend to exhibit in later measures, or delayed effects of increased fixations and increased regression path times on subsequent sections of the text.

Eye Movement Measures Compared to Other Measures of Cognitive Processing

Unlike reaction time (Just & MacDonald, 1989; Tian et al., 2010) and acceptability/congruency rating studies (Fraenkel & Schul, 2008; Paradis & Willners, 2006), eye tracking is able to provide a time course of how readers process sentences. This subsequently has allowed researchers to investigate at what stages of processing manipulated variables affects reading. Unlike self-paced reading tasks (Just, Carpenter & Wooley, 1982), in eye movement experiments, the items are presented to readers how they would normally read text. Self-paced reading study paradigms typically present one or two words at a time, with the participant pressing a button to indicate they have finished reading and wish to move onto the next section of text. The timing between stimulus presentation and the pressing of the button are used as an index for processing difficulty, and provide the metric of self-paced reading time. Longer self-paced reading times are found for text that is considered more difficult to interpret, such as garden-path sentences (see Ferrera & Henderson, 1990; Mitchell, 1987), providing evidence to suggest this metric is sensitive to cognitive processing. One limitation of this stimulus presentation method, however, is that it often means readers cannot regress back into the text when they encounter any processing difficulty.

Stunted presentation of linguistic stimuli leads to extraneous effects of the task, such as reading rates being around twice as slow as naturalistic reading (Rayner, Sereno, Morris, Schmauder & Clifton, 1989). A lack of parafoveal preview benefit (McDonald, 2006) or ability to skip words (Drieghe, Rayner & Pollatsek, 2005) are two natural aspects of sentence reading that are eliminated from self-paced reading experiments. The inability to regress back into the text during self-paced reading tasks does not allow readers to reanalyze what they have read. Regressive measures in eye movement experiments have successfully been used to show the point at which readers experience difficulty processing a sentence (Altmann, Garnham & Dennis, 1992; Rayner, Carlson & Frazier, 1983; Rayner & Sereno, 2004;). The point at which regressions are made and the time spent reprocessing text are important factors in understanding how the readers are affected by syntactic (Frazier & Rayner, 1982), semantic (Joseph, et al., 2008; Rayner et al., 2004) and pragmatic anomalies (Ferguson et al., 2008). An understanding that

cannot be gained by those methodologies that denies readers this option during language comprehension.

Similarly, the use of even-related potentials (ERPs), also suffers from the limitation of stimulus presentation. ERP measures reflect electrical brain activity changes in response to different stimulus presentations and cognitive processes. By averaging waveforms across a number of trials and participants, average waveform 'components' can be extracted. These components differ in terms of positivity, amplitude (measured as voltage) and latency (time from onset of stimulus). Combinations of these factors have been used to categorize components and correlate them with particular cognitive processes (Baccino, 2011). Saccadic eye movements, however, 'contaminate' ERP records, due to the contraction of ocular muscles creating electrical signals, meaning they do not reflect cognitive processing (Boylan & Doig, 1989). As a result, ERP studies often ask participants to restrict any eye movements and only fixate on the display, serially presenting word/s. This has the added benefit of limiting contamination between multiple cognitive processes across words (Dambacher & Kliegl, 2007). Similarly to self-paced reading time, this limits the ecological validity of ERP studies with relation to language comprehension, where a succession of eye movements (typically <300ms, Rayner, 1998) are made with cognitive processing concurrently. While ERPs can provide a high temporal resolution with regard to the time course of the effect of boundedness during reading, it is not possible to see how this affects language comprehension during typical reading. In later experiments in this thesis, eye movements across whole paragraphs of text are analyzed to investigate how readers recover from semantic incongruity, and where readers regress to in order to reach a coherent discourse representation. The specificity of these findings would be greatly reduced with the use of ERP methodology.

Eye tracking during reading, in contrast to the methods mentioned above, allows for an unimpeded and detailed investigation of natural visual behavior during reading. For instance, offline measures were shown to be insufficient for indexing constraints that decide initial sentence parsing of structural ambiguities online (Filik, Paterson & Liversedge, 2005). This has led to eye tracking experiments greatly informing the literature as to how negative quantifier focus

guide parsing decisions incrementally as we read (see Filik, Paterson & Sauermann, 2011). Similarly, the experiments within this thesis aim to provide evidence for the effect of boundedness on online processing during sentence comprehension, through the use of eye movements.

In summary, eye movement and reading research has grown massively in the last 40 years as a consequence the methodology's informativeness in explaining cognitive processing (this is also as a consequence of the increasing technological advancement of eye trackers themselves). This includes the semantic processing of words, with a range of effects found with relation to the integration of implausible concepts. This thesis will use eye movements during reading to investigate how readers are processing negated bounded and unbounded concepts. As has previously been discussed, commonly used paradigms in negation research, such as self-paced reading, alter how readers would normally read text. Other paradigms such as picture-verification tasks are also unable to give an uninhibited look at how readers process negation without implementing demands of the task upon participants. Eye movements are, therefore, an ideal methodology to explore the research questions in this thesis.

The proposed research into negation and boundedness in this thesis will represent the first attempt to show whether the semantic configuration of concepts is a linguistic source of information that readers consider online during reading. Most of the psycholinguistic literature into negation can only speak to how readers consider negation once they have already processed the negated entity. There is clear evidence, however, that readers incrementally interpret text, forming semantic interpretations word-by-word. In order to create a parsimonious account of negation processing, further research needs to investigate the moment-to-moment timecourse within which negation is read. This is particularly salient when the most popular theory of negation currently, the dynamic pragmatic theory, proposes readers use a large amount of contextual and pragmatic factors in order to efficiently process negation. One clear weakness in this theory, as it stands, is that it does not draw on evidence of online processing to show the effect of these factors as the negation is processed. The proposed research, therefore, not only seeks to show the

impact of boundedness on negation processing, but also that the effect of this linguistic variable is evaluated online during sentence comprehension.

Summary

This review has looked at several phenomena in the psycholinguistic literature regarding negation and the linguistic operator of boundedness, before reviewing eye movement and reading methodologies. Accounts of negation have largely been shaped by the theory of language that is prevalent at the time. When it was assumed that semantic information was computed on a propositional level (rather than at a word or sentence level), negation was considered as a transformation, which manipulated the parsing of that sentence (Klima, 1964). As propositional theories of meaning (Klein, 1980; 1982) and findings of negation's apparent processing cost compared to affirmation (Chase & Clark, 1971; Clark & Chase, 1972; Just & Clark, 1973) became prevalent, negation was considered as an extra processing step required for successful comprehension.

As embodied theories of cognition became prevalent (Zwaan, 2003; Zwaan & Radvansky, 1998), it was suggested that experiential simulations underlie comprehension. Negation was regarded within a specific timeframe, specifically the affirmative sensorimotor simulation being instantiated, before being suppressed to create an accurate representation (Kaup, 2001; Kaup & Zwaan, 2003; Kaup, Ludtke & Zwaan, 2006). This was because the absence of a concept cannot be captured within a sensorimotor simulation (*he was not waving* has no explicit experiential marker). Finally, as constraint satisfaction theory became popular in the sentence processing literature, Dynamic Pragmatic theory has rejected the notion of obligatory suppression in the comprehension of negated entities. Contextual priming of negation through clefting, (Tian et al., 2010) and pragmatic or contextual licensing (Giora; 2006; Nieuwland & Kuperberg, 2008) have all been shown to allow negation to be processed markedly more similar (at least in terms of speed) to affirmation than when studied in isolation (Carpenter & Just, 1989).

Furthermore, the linguistic operator of boundedness has also been shown to have an effect on the processing of negation (Fraenkel & Schul, 2008; Paradis & Willners, 2006). The ontology of a concept affects how it is negated. If the concept is

bounded, the ontology of the concept is split into two clear representations, whilst unbounded concepts possess a scalar ontology (Ladusaw, 1996) with many possible representations across the scale. As we have seen with the creation of multiple and single alternative contexts (Anderson, Huette, Matlock & Spivey, 2010; Beltran, Orenes & Santamaria, 2008), the negation of a bounded concept (*not dead*) should rapidly instantiate a single representation (*alive*). This is compared to unbounded concepts, which mitigate a reader's level of negation down a scale, so *not small* does not necessarily instantiate a representation of *big*. This has also been considered within a mental model theory of comprehension (Fauconnier, 1985, 1994, 1997).

Finally, this review has considered the growing popularity of eye movement studies due to the tight coupling of eye movements measures to cognitive processing (Liversedge & Findlay, 2000; Rayner, 1998, 2009). Most importantly, eye movement studies of semantic processing have revealed a clear disruption of typical reading behavior when readers encounter content that they are unable to integrate into their discourse representation.

Discussion: Direction for the Present Thesis

Considering the prominence of negation in language, there remains a certain lack of understanding about how it is instantiated into a reader's discourse representation. As opposed to previous views that negation could only deny/reject, or signal the absence of an entity, theorists are beginning to understand negation within the many contexts that it is used. As well as context, it is being seen how properties of the entity being negated also affect negation, such as how many alternatives that negated entity can generate. Furthermore, the vast majority of the psycholinguistic literature has used methodology unequipped to elucidate the online process of negation. The lack of eye movement data within the section of the field is an issue pointed toward in this Literature Review. The extensive eye movements and reading literature can be used to further investigate higher-level linguistic processes.

The initial aim was to understand the impact of boundedness on the instantiation of negated representations into a readers' discourse. The empirical work in this thesis will begin with the creation of a set of bounded and unbounded

antonym pairs (Experiment 1B) that do not differ in other lexico-semantic relations (Experiment 1A) and their embedding into contexts where they can conflict or complement (Experiment 1C). With the first creation of such a stimuli set, it is possible to focus on investigating how these antonym pairs are processed online when negated. Furthermore, these experiments will be amongst the first investigating negation, and the very first to look at boundedness as an online linguistic operator during language comprehension (Experiment 2). Experiment 3 looks at whether this speed of negation can be facilitated with the introduction of linguistic markers to indicate an upcoming dis/agreement. While it is clear that unbounded negation is ambiguous, it is not known how this is explicitly represented in discourse. Experiment 4 investigates whether readers instantiate an indefinite representation, or whether readers instead choose to instantiate the antonym of an unbounded negation, in order to overcome the ambiguity.

These findings extend our current understanding of negation, specifically cases where negated representations can immediately be instantiated, and when they cannot. It is well documented that negation without context takes longer to process than its affirmative equivalent (Carpenter & Just, 1975; Chase & Clark, 1971; Clark & Chase, 1972; Just & Clark, 1973; MacDonald & Just, 1989). It is widely suggested this is because the negation is unmotivated, suggesting negation requires a clear contrast in order to be processed efficiently (Givon, 1978; Grice, 1967). This has been strengthened by findings suggesting negation can be processed as quickly as affirmative sentence. Specifically when the negation is clefted (Tian et al., 2010), contextually supplemented in order to suggest an incoming contrast (Dale & Duran, 2011; Nieuwland & Kuperberg, 2008) or is only capable of being interpreted as one state (Huette et al., 2013). Findings to suggest bounded negation can be processed more efficiently than unbounded negation would further strengthen this principle. Furthermore, it would provide further evidence for Dynamic Pragmatic accounts of negation processing. The Dynamic Pragmatic account suggests a range of contextual, linguistic and pragmatic factors affect negation (Giora, 2006). The findings documented here will provide evidence of another variable that affects online interpretation of negation, providing further grounding for this theory in explaining negation processing.

Chapter 2

Investigating Readers' Interpretations of Boundedness During Offline Judgement Tasks

Introduction

As noted in the literature review, it has been shown that the way negation is processed, and subsequently interpreted, varies dependent on a number of contextual, lexical and pragmatic variables. Moreover, one key variable within this is the number of alternatives suggested by a negated concept. Several studies have explored this process using offline ratings and tasks using mouse tracking and the visual world paradigm (Anderson, Huette, Matlock & Spivey, 2011; Beltran, Orenes & Santamaria, 2008; Fraenkel & Schul, 2008; Paradis & Willners, 2006). Ultimately, subsequent experiments within this thesis aim to explore whether the number of alternatives suggested by a negation are processed online during language comprehension. This will be explored through the variable of boundedness, by exploring bounded concepts that have a semantic configuration of two, categorical states (e.g. *dead/alive*), and unbounded concepts with scalar semantic configurations of more than two states (e.g. *wide/narrow*).

This chapter consists of three experiments that explored the influence of the variable of boundedness on offline, semantic interpretations of negation. While in subsequent chapters, eye tracking during reading is used to explore whether boundedness influences online computation of semantic meaning, in this chapter, readers' ultimate interpretation of text was tested. The aims of this chapter were two-fold. The first aim was to establish whether readers are sensitive to the linguistic operator of boundedness during reading. The second aim was to validate that the initially supposed bounded and unbounded stimuli possessed the boundedness properties that had been applied to them.

Within Experiment 1a an antonym elicitation experiment was used, in which it was investigated whether the bounded and unbounded word pairings all shared the same lexical relation of canonical antonymy (strongly coupled opposites, e.g. *good/bad*), regardless of boundedness. In Experiment 1b, it was investigated whether

readers were sensitive to the linguistic operator of boundedness when making judgments about a single sentence of text. Finally, in Experiment 1c, a further study was employed to investigate whether readers were still sensitive to the variable of boundedness when negated bounded and unbounded items were presented within a passage of text. The stimuli discussed in Experiment 1c will also be used in Experiment 2.

Experiment 1a: Antonym Elicitation of Bounded and Unbounded Items

Antonyms are one of the most prominent semantic relations between lexical items and, since the 1960s, have been shown to be an important feature of language development (Bierwisch, 1967). Antonym pairs refer to pairs of opposite words that cannot be co-expressed (Jones, Paradis, Murphy & Willners, 2007). 'Antonymy' refers to the oppositeness of the relation between antonyms (Lyons, 1977). Deese (1964) confirms that antonyms are the most commonly elicited words during word association tasks, suggesting antonymy as one of the strongest semantic connections that exist between pairs of words.

Clark's (1973a, 1973b) semantic feature hypothesis predicts that children use the relationship between antonyms to develop their understanding of concepts. For example, for the concept of *size* they use the relationship between *big* and *little* to gain an understanding of this concept in the world. From this general definition, children then learn to apply this relationship to a larger range of more specific expressions of relationships. For instance, once a child has learnt the generic terms to express *size*, they will apply it to *height*, *width* and then *weight,* learning the relationship between *tall/short, wide/narrow* and *heavy/light*. This suggestion was supported by data showing children in early stages of language development perform better in antonym elicitation tasks when faced with pairs such as *big/little* and *long/short* than *wide/narrow* or *thick*/*thin* (Clark, 1972). This effect was absent in children in relatively later stages of language development. This suggested more generic antonyms are learned first, and provide the foundation to learn more specific concepts.

Antonym elicitation involves participants giving the best opposite to a word, or rating the strength of the association between two separate words, and has been used to measure the lexico-semantic relation of antonymy (Clark, 1970; Paradis, Willners, Lohndorf & Murphy, 2006; Tribushinina & Dubinkina, 2012). Clark defines antonym elicitation as finding the antonym with "minimum contrast", in that the words only differ in one aspect, the polarity of the dimension they represent. Furthermore, Cruse (1986) cites the "simultaneous closeness and distance" antonyms share in his definitions of antonyms. Within this definition, antonyms only differ on one characteristic, polarity. While d*ead* and *alive* are distant in that they refer to mutually exclusive opposites, they are semantically very 'close' in that they both refer to the same concept, *mortality*.

In Experiment 1a, an antonym elicitation experiment was used to validate that the antonyms that have been chosen share the lexical semantic relation of antonymy. Antonym pairs that meet this criterion were defined as referring to the same semantic dimension, which was either bounded or unbounded, with each antonym of a pair being a polar state within this dimension. This also meant that any manipulation of boundedness was conducted upon antonym pairs that shared a very specific semantic relationship. Specifically, they were all canonical antonyms (see below). This removes the semantic relationship between pairs as a potential confounding variable in subsequent experiments.

Antonym canonicity is the term used within the linguistic literature to denote the level to which two opposing lexical items can be said to be opposable. Canonical antonyms are two words that are the most clearly opposable and conventionalized as opposites within a language (Murphy, 2003). For example, *hot-iced* are technically antonyms (or at least opposites), but they do not prime each other to the degree that *hot-cold* do in language production tasks, as only the latter are considered canonical antonyms. Although there is a range of different 'opposites' to the word *bad (satisfactory, agreeable,* etc.) *good* has been conventionalized as the canonical antonym within the English language and has been shown to be much more prevalent within elicitation experiments (Murphy & Andrew, 1993).

There is experimental evidence that has shown canonical antonyms were assessed as 'better' opposites offline (Charles & Miller, 1989; Palermo & Jenkins, 1964) and were elicited much quicker (Herrmann, Conti, Peters, Robbins & Chaffin,

1979) than non-canonical antonyms. These findings suggest antonym elicitation is a viable method for understanding the lexical semantic relationship of antonymy. Furthermore, ERP experiments have shown an effect of antonym canonicity on semantic processing. Van de Weijer, Paradis, Willners and Lindgren (2014) used a semantic categorization task where participants had to decide whether a word was unrelated, a canonical antonym, or non-canonical (e.g. *wide-hard, dead-alive* or *happy-grumpy* respectively). If canonical antonyms shared the same semantic relationship as other opposites, no difference would have been expected in the ERPs recorded during the categorization task. Their results clearly found a significantly smaller N400 (that is, an ERP component associated with a lack of semantic fit between a word and its context, Kutas & Hillyard, 1980) in the case of canonical antonyms, compared to the unrelated words, but more importantly compared to the non-canonical antonyms. This smaller N400 effect is usually found when priming target words (Kutas & Hillyard, 1980; Lau, Phillips & Poeppel, 2009) or facilitating them through context (Lau, Almeida, Hines & Poeppel, 2008) and is considered to show an ease of semantic integration of multiple items. It can be reasoned, therefore, that canonical antonyms hold a special status in semantic processing, due to their conventionalized pairing within language understanding. It was important, therefore, to ensure that the bounded and unbounded antonyms did not differ in whether they were canonical pairs or not. If both canonical and non-canonical antonyms were used, it is possible that this established semantic effect would have also had an effect upon readers' responses (offline and oculomotor in subsequent chapters) to the bounded and unbounded stimuli.

Justeson and Katz (1991) have explained the antonym priming effect as an artefact of antonym-pairs' co-occurrence within text, using corpus analyses. They found extremely high co-occurrence rates for antonyms when compared to semantically related controls. Furthermore, they suggest that this high co-occurrence was also the cause of the formation of an antonymic association and is the reason for any 'special' relationship between canonical antonyms, compared to non-canonical antonyms. Any effects of canonicity were, therefore, ascribed as a direct result of co-occurrence frequency.

Van de Weijer, Paradis, Willners and Lindgren (2012) also found a priming effect in word association for antonyms, but this priming effect was significantly stronger

when compared with lexical pairs of equal co-occurrence ratings. These data do not support Justeson and Katz' (1991) co-occurrence hypothesis. Instead, it was suggested that the strength of semantic association between antonyms occurs due to their important role in relation to the semantic representation of concepts. The high co-occurrence of canonical antonyms was, instead, due to their specialized status in language, causing them to be used together to such a high degree. Furthermore, it has been suggested that the combination of high co-occurrence and strong lexical semantic relationship causes canonical antonyms to be such strong priming agents of each other.

Paradis, Willners and Jones (2009) employed an antonym elicitation experiment and found canonical antonyms to have a privileged relationship compared to other antonyms. Canonical antonyms, such as *happy-sad* were found to co-occur at higher rates than non-canonical antonyms, such as *happy-grumpy*. Furthermore, they were elicited at a higher rate, with fewer alternative items elicited, and rated as 'better' antonyms by participants. Paradis et al.'s data converge with previous findings to suggest that there is only a relatively small set of words with such a strong coupling, evidenced by high elicitation and co-occurrence rates. Experiment 1a aimed to validate that a set of antonyms that possessed the relationship of being extremely canonical antonym pairs, and were interpreted as such by participants. As such, when these pairs were subsequently used to manipulate boundedness, it could not be argued that any effects of interpretation were based on the lexical semantic relationship shared between antonym pairs. Experiment 1a aimed to ensure a high strength of canonicity between each pair, and ensure as little variability in this relationship as possible.

One further consideration to be taken into account in Experiment 1a was the issue of lexical ambiguity. For instance, in Paradis, Willners and Jones' (2009) study, *light* was seen as much more conventionalized to *dark* than *heavy,* an effect of lexical ambiguity where its use to denote the dimension *shade* is dominant over its use to denote the dimension *weight*. While this is certainly a confounding variable when presenting words in isolation, there has been empirical evidence showing that this dominance is reduced by a facilitative context (Kambe, Rayner & Duffy, 2001; Rayner, Pacht & Duffy, 1994; Sereno, Pacht & Rayner, 1992). In Experiment 1a, lexically ambiguous items such as *light* were provided within contexts that disambiguated

which sense was intended (e.g. *the colour/package was light,* each respectively refer to the *shade* and *weight* senses of *light*), in order to obtain canonical antonyms in both senses, if they were evident. Previously, Murphy and Andrew (1993), have manipulated context for lexically ambiguous items and found that antonyms and synonyms elicited were significantly different depending on the context. This indicates the importance of providing context in order to explore the antonymy relationship between multiple dimensions.

Experiment 1a was motivated by a wealth of evidence describing canonical antonyms, a lexical semantic relation that has elicited a range of facilitatory effects in elicitation, ERP and corpus studies. Experiment 1a aimed to create a stimulus set of canonical antonyms, using an untimed elicitation methodology. Furthermore, as words being used could be lexically ambiguous, they were embedded in disambiguating sentence contexts. It was predicted that there would be no significant difference in elicitation rate between the bounded and unbounded antonyms. That is to say, it was expected that participants would produce the appropriate antonym partner for each instance of a pair, and that this would be comparably the case for bounded and unbounded antonym pairs. The stimuli here were not designed to differ in any semantic variable except that of boundedness. This meant the bounded and unbounded stimuli were not designed to differ in their lexico-semantic relationship of antonymy.

Experiment 1A: Methodology

Participants

Sixteen participants (nine females) with a mean age of 24 (range 18-33) from the University of Southampton undergraduate population took part in exchange for course credit or a small cash payment (£6 per hour). All subjects were native English speakers. Participants who took part in this study were not allowed to take part in any subsequent experiment (Experiments 1b, 1c, 2, 3 or 4).

Materials and Design

Thirty-six bounded and 36 unbounded antonym pairs were devised based on Paradis' (2001, 2003) description of boundedness (this aspect was further explored in Experiments 1b and 1c). The antonyms were a mix of adjectives, verbs, nouns and

adverbs. Thirty-one of these antonym pairs were taken from previous studies of boundedness, specifically, Paradis and Willners (2006), Fraenkel and Schul (2008) and Mayo, Schul and Bernstein (2003). The remaining items were taken from an antonym dictionary (Kroiz, 1972).

To ensure an item was not primed by the presence of its antonym, each participant only saw one member of the pair. The study used a within-participants design with the independent variables of boundedness (bounded vs. unbounded) and antonym polarity (positive or negative polarity). Participants completed one of two lists, with polarity counterbalanced across the lists, meaning participants only saw one type of antonym from each antonym pair. The dependent variables were the prevalence of antonym elicited (%) and number of alternatives elicited.

Procedure

Participants took part in the study by completing an online survey, distributed through the University of Southampton's '*efolio research'* service. Participants were instructed that they would be taking part in a study looking into lexical semantics and opposites. Participants were not informed of any other theoretical motivations for this experiment until a debriefing screen was presented on completion of the experimental session. They were presented with 72 clauses containing a word in bold. Participants were instructed to provide "the best single word opposite" for each word in bold. The clauses the antonyms were presented within maintained the antecedent that was used for Experiments 1b and 1c onwards, e.g. *the patient is dead/alive* or *the grass was long/short*. As discussed, these clauses were used to avoid any effects of lexical ambiguity, as the clauses clearly disambiguated which sense of the word was intended. The contexts did not change between the negative and positive antonym. The stimuli were presented in six blocks of 12 and this was completed in one session, taking between 10-25 minutes in total. A full list of materials can be found in Appendix A, including the context clauses the antonyms were presented within.

Experiment 1A: Results and Discussion

Responses were collated and ratios of how often each response was elicited in relation to each antonym were scored. To avoid any variation in participant response preferences, all responses featuring the root lexeme were placed in the same category. For instance, in response to the opposite for *the child was* ***happier****,* the responses *sadder* and *sad* were both accepted into a single score or for the opposite of *the hostages were* ***free****;* the responses of *captive* and *captured* were both accepted into a single score. The responses from the experiment fell into two categories, 1) those that were predicted as the canonical antonym, which accounted for 86.96% of all 1152 responses, and 2) those not predicted as the canonical antonyms.

The qualifying criterion for each antonym to be considered canonical was that the antonym was elicited at least 75% of the time (across both pairs) and no more than three different words were elicited as the antonym from all participants. The 75% threshold was chosen to ensure that antonyms being used were considered to be the dominant and associative opposite within the dimension they denote (Paradis, Willners & Jones, 2009). No more than three different responses were allowed to ensure a strong conventionalized coupling of the antonyms (Murphy, 2003). Sixty-six of the antonym pairs met both these criteria. Of those that did not, two were discarded (*certain-doubtful* and *taken-free*). These were replaced with pairs that use the root lexeme of other, accepted, pairs (e.g. *earlier-later*, as well as *early-late*). For *shown-concealed, sceptic-believer, demand-offer, hero-coward* and *improved-declined*, the most pair was altered to include an alternative antonym that participants elicited. To ensure both items of the pair met the criteria, a follow-up study was run with eight of the original participants using the same methodology. From the follow-up study, it was found that *shown-hidden, atheist-religious*, *demand-request, brave-cowardly* and *improved-deteriorated* were all antonymic pairs that met the qualifying criterion. In the case of *shown-concealed, hidden* was the canonical antonym for *shown;* a relationship that was found to be reciprocal in the follow-up study. *Believer* was not found to be a canonical antonym for *atheist*, but *religious* was. *Offer* was not found to be a canonical antonym for *demand*, but *request* was. *Hero-coward* only elicited each other 68.75% of the time, but *brave-cowardly* elicit each other 93.75% of the time with minimal changes to context. Finally, the first test showed *improved* elicited *deteriorated* 100% of the time, the follow up found this relationship to be reciprocal

(also 100% response rate). All antonym pairs and their elicitation rate can be found in Tables 2.1 and 2.2.

Table 2.1. Unbounded antonym pairs and their elicitation rate in Experiment 1a.

Unbounded Antonym Pair	Elicitation Rate (%)
Good - Bad	100
Late-Early	100
Sad-Happy	93.75
Rough-Gentle	81.25
Shallow-Deep	100
Empty-Full	100
Easy-Hard	93.75
Heavy-Light	100
Old-New	100
Hotter-Colder	81.25
Hot-Cold	100
Sadder-Happier	100
Sad-Happy	93.75
Tall-Short	93.75
Higher-Lower	100
High-Low	100
Sweet-Sour	81.25
First-Last	100
Worst-Best	93.75
Clean-Dirty	93.75
Light-Dark	100
Stupid-Intelligent	81.25
Thinly-Thickly	100
Sadly-Happily	93.75
Gently-Violently	75
Cowardly-Brave	93.75
Pride-Shame	81.25
Contracted-Expanded	75
Shouting-Whispering	87.5
Fast-Slow	93.75
Improved-Deteriorated	100
Loud-Quiet	93.75
Good-Bad	100
Strength-Weakness	100
Serious-Minor	81.25
Victorious-Defeated	81.25

Table 2.2. Bounded antonym pairs and their elicitation rate in Experiment 1a.

Bounded Antonym Pair	Elicitation Rate (%)
Alive-Dead	100
Closed-Open	93.75
Tidy-Messy	100
Free-Captive	81.25
Vague-Clear	75

Victory-Defeat	87.5
Truth-Lie	93.75
Success-Failure	93.75
Failed-Passed	100
Religious-Atheist	87.5
Original-Copy	93.75
Demand-Request	93.75
Leader-Follower	93.75
Guest-Host	81.25
Conflict-Peace	100
Female-Male	93.75
Shown-Hidden	81.25
Deny-Admit	81.25
Accepted-Rejected	87.5
Open-Closed	100
Survived-Died	81.25
Hit-Missed	100
Fail-Pass	100
Illegally-Legally	87.5
Accidentally-Intentionally	87.5
Fantasy-Reality	81.25
True-False	93.75
Dangerous-Safe	93.75
Sharp-Blunt	100
Intact-Broke	81.25
Wet-Dry	100
Failed-Passed	100
Accidental-Intentional	87.5
Absent-Present	87.5
Awake-Asleep	100
Innocent-Guilty	100

From these results, 72 antonym pairs were identified that met the criterion of being canonical antonyms. This meant they all shared the same lexico-semantic relationship of antonym. The intended antonym was elicited in 92.4% of cases within this final set of antonym pairs.

To further ensure there were no differences between the lexical semantic relationships within the bounded and unbounded antonyms, a statistical comparison was conducted between how often bounded and unbounded antonyms were elicited (expressed as a percentage). A paired *t*-test found no differences of antonym prevalence between the bounded (M=91.84, SD = 9.42) and unbounded (M = 92.88, SD = 9.80) conditions (t (71) = 0.69, p = .25). While the antonym pairs differed in

whether they were used to express a bounded or unbounded concept, no difference was found in the strength of antonym relationship each pair shared. Participants were equally likely to elicit the appropriate antonym in the bounded and unbounded conditions. In subsequent experiments, it was investigated whether readers were sensitive to the variable of boundedness during reading. This manipulation could now be conducted without any potential confound of the strength of antonymy relationship between pairs. To be clear, all items used in subsequent experiments in this thesis are canonical antonyms. In Experiment 1b, the differentiation of boundedness between the two stimuli sets was validated. Any interpretation differences between the two stimuli sets would, therefore, indicate a systemic difference in readers' understanding of bounded and unbounded concepts

Experiment 1B: Interpretation of Boundedness in Offline Sentence Ratings

The aim of Experiment 1b was to test whether readers were sensitive to the linguistic operator of boundedness during offline interpretation. As noted in the literature review, bounded dimensions represent a dichotomy (e.g. *alive*/*dead*). The two are mutually exhaustive, there are no other states within the dimension, and mutually exclusive, as one cannot be both antonyms simultaneously (Paradis & Willners, 2006). Unbounded dimensions are scalar, with many different states in between the antonyms (*wide/narrow*). It has even been suggested that unbounded states are not mutually exclusive of each other in the most literal sense, as the applicability of an unbounded state is subjective. Kennedy and McNally (2005) discuss 'open' unbounded scales as being guided by context. For instance, while someone may describe someone who is over six feet in height as being *tall*, they could still be classified as *short* within the context of *basketball players*, whom are all ordinarily above this height. In Experiment 1b, a sentence-rating study was used to investigate whether readers could interpret this difference by negating bounded and unbounded canonical antonyms from Experiment 1a.

Fillenbaum (1966) provided one of the earliest experimental manipulations of antonymy form to investigate its effects on negation interpretation. Two groups of

antonym pairs were defined, contrary and contradictory. Contrary antonym pairs denoted scalar properties where the absence of both antonyms is possible, while contradictory antonyms were jointly exhaustive, the negation of one antonym **must** entail the other. Participants were required to listen to 96 sentences featuring negation and then completed a recall test. Contradictory negations were more likely to be recalled as their antonym than contrary antonyms, which were more likely to be remembered in their negated form. For instance, *the sailor was not alive* was more likely to be remembered as *the sailor is dead* than *the drink was not cold* was to be remembered as *the drink was hot.* Fillenbaum posited that this was because in the former case, meaning is being maintained; as to remember the *sailor* as *dead* is the same as *not alive*. As *dead* is computationally less to remember than *not alive*, it was efficient for participants to make this transformation and remember the sentence in this format. This is compared to remembering the *drink* as *hot,* which is not the same as remembering it as *not cold*, as there are alternative temperatures possible in this scenario. Participants, therefore, did not transform this sentence into a simpler format, as it would not be possible to remember the alternatives besides *hot* available within this sentence.

Fillenbaum's (1966) study was one of the first pieces of empirical evidence to suggest readers are sensitive to the semantic configuration of negated items. Participants transformed contradictory statements because they viewed *not alive* as semantically equivalent to *dead,* as there is no alternative state that could be inferred from that negation. As *the drink was not cold* can imply states other than *hot*, readers retained the negation to denote the ambiguity of the temperature. Participants were also asked to make 'equivalence judgments', rating the semantic similarity of contradictory and contrary negations with their antonyms. Participants rated contradictory negations as being more equivalent to their antonym than contrary antonyms. For example, *not dead* was rated as more equivalent to *alive* than *not hot* was to *cold.* These findings have since been shown to be experimentally robust across multiple languages. For instance, Brewer and Lichtenstein (1975) replicated a functional difference between contradictory and contrary antonymic negation, with contradictory negation being more likely to be recalled as their affirmative antonym than contrary negation. Furthermore, the literature review described supporting

evidence of this effect in Swedish (Paradis & Willners, 2006) and Hebrew (Fraenkel & Schul, 2008). Bounded entities only possess two possible states (e.g. *dead/alive*), thus a bounded negation has very little ambiguity and is interpreted as the one possible state. Unbounded entities possess many possible states across a dimension of meaning (e.g. *hold/cold*), thus an unbounded negation is much more ambiguous, as it could refer to any number of states, leading to a more uncertain interpretation.

In Experiment 1b, the aim was to replicate the equivalence rating effect, to show readers are sensitive to boundedness when interpreting negation. Furthermore, this serves as a validation of the manipulation of boundedness. Experiment 1b does differ from the aforementioned studies of negation interpretation in a number of ways. For instance, modern studies that have considered boundedness/contradictory negation have been carried out in Hebrew/Swedish (Fraenkel & Schul, 2008; Mayo et al., 2004; Paradis & Willners, 2006), whereas this effect was validated in English in Experiment 1b. This was of particular interest due to the contrast between English and Hebrew, as the latter language lacks prefixal negation (e.g. *un-, non-).* It has been previously noted that prefixal negation does not act as a logical operator (Sherman, 1973). For instance, *unhappy* is considered more similar to *sad* than *not happy*. Without a specific way of asserting "weaker" negation, Mayo et al. suggest that negation in Hebrew may always be inherently more ambiguous than in languages with prefixal negation. If there are fewer methods for expressing negation in that language, the logical assumption is that the negative operator *not* must fulfil a larger range of roles in that language, increasing its ambiguity.

Paradis and Willners' (2006) study of boundedness used three predicates in order to consider the effect of boundedness on negation interpretation. For instance, *small/big* statements *were* rated along a scale that began with *pixie* and ended with *giant*. The current experiment does not rely so heavily on exemplars, and will follow an equivalence rating methodology, as seen in Franekel and Schul (2008). For example, *how similar are 'the patient is dead' and 'the patient is not alive?'* This linguistic test allowed for an investigation of how the words were interpreted without the introduction of exemplars of adjectives. In Experiment 1b, the scales of Fraenkel and Schul's study were adapted to a more conventional 7-point rating system, as opposed to the 20-point previously used. This is a more widely credited response

scale, as any more than 11-points on a rating scale has been shown to cause respondents to adhere to the scale less reliably (Kerlinger & Lee, 2000; Nunally & Bernstein, 1994). As such, participants could be less able to interpret the scale and do not give a clear and accurate response of their interpretation of the text. Furthermore, Paradis and Willners tested bounded and unbounded negation over separate samples in separate experiments, whereas the current study features a between-participants design.

Mayo et al. (2004) did not consider semantic configuration in their tests of the effects of number of alternatives on negation processing. Mayo, et al. assessed concepts expressed by antonyms (bi-polar – *hot/cold*) and those that were not (uni-polar - *adventurous*). Their validation of their manipulation also used an antonym elicitation test. Their criteria for bi-polar antonyms were items that received only one response in 80% of cases, while unipolar items were items where 80% of participants failed to give a single word antonym. This is a clear divergence from the current stimuli, which all broadly met the former criterion, as the experiments detailed here manipulate the number of states between antonyms, which define a concept's semantic configuration. Similarly, Franekel and Schul defined contradictory antonyms as those where only one negated antonym could be true at any one point. For instance, *a door* cannot be *not closed* and simultaneously *not open,* whereas *coffee* can be *not hot* and *not cold*. Fraenkel and Schul, however, did not directly reference semantic configuration or boundedness in their experiments. While their criteria were included within those in Experiment 1b, the stimuli also adhere to Paradis' (2001; 2004) principles of boundedness, described previously.

In summary, the aim of Experiment 1b was to test whether readers were sensitive to the linguistic operator of boundedness during offline sentence interpretation, replicating previous experiments. Furthermore, Experiment 1b acted as a validation of the boundedness manipulation. In Experiment 1a, a stimulus set of 72 antonym pairs that did not differ in the lexical-semantic relationship they shared were established, specifically they were all canonical antonyms. In line with the above research on negation and boundedness (Fraenkel & Schul, 2008; Paradis & Willners, 2006) it was predicted that boundedness would affect the interpretation of a negated

sentence. Specifically, it was predicted that negated unbounded items would be rated as less similar to their antonym than bounded negation. To reiterate, bounded negation is unambiguous, as there are only two possible states within that dimension. Informing the reader that one state is not true can only lead to the assertion that the only other alternative state is (*not dead* can only lead to an interpretation of *alive*). Thus, *not alive* is semantically equivalent to *dead,* and should be rated as such, if readers are sensitive to boundedness when interpreting negation. Unbounded negation is more uncertain, as the semantic configuration of an unbounded concept features at least one state in between the two antonyms. Informing the reader that one unbounded state is not true leads to multiple alternatives (*not hot* presents the possibility of *cold* as well as many other states in between). Thus, *not hot* is not considered semantically equivalent to *cold*, and should be rated as being less semantically similar than bounded items (such as *not dead* to *alive*).

Experiment 1B Methodology

Participants

Fourteen participants (10 females) with a mean age of 24.79 (range 18-41) from the University of Southampton took part in exchange for course credits or a small cash payment (£6/hour). All participants were native English speakers. Participants who took part in this study were not allowed to take part in experiments 1c and 2 and had not taken part in Experiment 1a.

Design and Materials

The 72 canonical antonyms from Experiment 1a were split into two categories based on the predictions of boundedness. This categorization was in accordance with the original rules of boundedness presented by Paradis (2001). This included the rule that bounded concepts could possess only two possible states that were mutually exhaustive, while unbounded concepts featured more than two states, thus the two antonyms were not mutually exhaustive.

To quantitatively test the boundedness categorizations, a questionnaire was devised to test the similarity of negated bounded and unbounded concepts to their affirmative antonyms. The methodology used by Fraenkel and Schul (2008) was

adapted, specifically, participants were presented with pairs of sentences on a computer screen, one after another. Where previous studies have restricted themselves to adjectives, the stimuli here were not, including verbs, adverbs and nouns as well. One sentence contained an antonym within a negated, minimal context (e.g. *the patient was not alive)*, and the other contained the other antonym in an affirmative, minimal context (*the patient was dead*). A 7-point scale (1- completely identical, 7 completely different) was presented below upon which participants rated the similarity of the two sentences. These sentence pairs were placed into two lists, to counterbalance for antonym order (one list contained: *The patient is not dead. The patient is dead,* and another contained: *The patient is not alive. The patient is dead).* Participants rated 144 sentence pairs (72 bounded and 72 unbounded). Furthermore, 24 completely unrelated pairs were included (e.g. *the kettle is not rusting, the kettle is boiling* or *the kettle is not boiling. The kettle is rusting)* which also contained the negation of a dimension and the affirmative of a completely unrelated dimension. These were used to anchor participants' *completely different* end of the scale. This created a total of 168 pairs of sentences in total to be rated.

The sentences that the antonyms were presented within maintained the antecedents that were also used in Experiments 1a and 1c (e.g. *the* ***patient*** *is dead/alive* or *the* ***grass*** *was short/long)*. The placement of the antonyms within these clauses was to allow readers to access the dimension they were judging in the manner that they would in subsequent Experiments (1c and 2). The contexts did not change between the negative and positive antonym.

The 168 sentence pairs were presented in a randomized order. The experiment manipulated the between-subjects independent variable of boundedness (bounded vs. unbounded). The dependent variable was participants' resemblance ratings along a 7-point scale. A full list of materials can be found in Appendix B, including the context clauses the antonyms were presented within.

Procedure

Participants took part in the study by completing an online survey, distributed through the University of Southampton's '*efolio research'* service. Participants were instructed that they would be taking part in a study looking into the semantic

equivalence of different scenarios. Participants were not informed of any other theoretical motivations for this experiment until a debriefing at the end of the experimental session. They were then presented with the 168 pairs of sentences. Participants were instructed to rate the resemblance of each pair on a seven-point scale, with 1 being *completely identical* and 7 being *completely different*. Participants used the mouse to click on the number they wished to provide for each rating. The stimuli were presented in seven blocks of 12 pairs, which participants finished in one session, taking between 20-40 minutes in total.

Experiment 1B: Results

All 2352 responses were collated and the average resemblance scores were calculated by averaging each item's resemblance rating across both orderings of antonyms. The total means of the two conditions (bounded vs. unbounded) were calculated based on 28 ratings per item. It was found that unrelated pairs received an average score of 6.8, showing that they did not resemble each other at all.

Mean similarity scores can be seen in Table 2.3. To test the hypotheses, a paired t-test was carried out on the resemblance responses and, as predicted, found a significant difference between the bounded (M = 1.51, SD = 0.44) and unbounded (M = 3.17, SD = 0.87) conditions (t (71) = 15.41, p<.001). This pattern was consistent with the prediction that bounded negations would be interpreted as their antonym, evidenced by high similarity scores. This was compared to unbounded negations, which were rated as significantly less similar, with higher variance, indicating that unbounded scores were more variable than bounded scores. This was consistent with the prediction that unbounded negation is not interpreted as its antonym, due to the other alternative, possible states.

Table 2.3. Mean similarity ratings in Experiment 1b.

Condition	Mean	SD
Bounded	1.52	0.44
Unbounded	3.17	0.87
Unrelated	6.80	0.21

Experiment 1B: Discussion

The aim of Experiment 1b was to test whether readers were sensitive to the linguistic operator of boundedness during offline sentence interpretation and validate the boundedness manipulation. The results of Experiment 1b indicated that negated unbounded concepts were viewed as having less semantic equivalence to their antonym than in the bounded case. These results met the predictions made, driven by the theoretical assertion that unbounded dimensions feature more than two states within their semantic configuration. As a result, it can be asserted that unbounded negation can indicate states that are not necessarily their antonymic meaning (*not early* can mean *on time* as well as *late*). The negation of a bounded concept, however, instantiates a representation of its antonym, as only one state is possible, meaning it is semantically equivalent to its antonym. Furthermore, Experiment 1b was a successful replication of previous studies of boundedness (Fraenkel & Schul, 2008; Paradis & Willners, 2006) done in English using a set of stimuli that were not affected by the use of exemplars to advocate a scale and using a more conventional scale that participants could accurately comprehend. It has been shown, in Experiment 1b, that when communicators negate propositions, the process differs significantly depending on the boundedness of a predicate in that proposition.

The fact that these results validate the assertions of boundedness allows for further testing of how boundedness affects negation interpretation. In Experiment 1c, this stimulus set of 36 bounded and 36 unbounded antonym pairs were placed into passages. This also served to validate the manipulation within a longer context, and investigate how readers integrate multiple bounded and unbounded representations. For instance, from the results of Experiment 1b, it was possible to generate the prediction that readers will interpret two unbounded negations as more similar than two bounded negations. As neither *not early* and *not late* resembles their antonym, readers can presumably resolve these two negations by interpreting them as both referring to conciliatory state (in this example, *on time*). This is compared to two bounded negations, which should be interpreted as completely different from each other. *Not dead* can only posit the state of *alive*, while *not alive* can only posit the state

of *dead.* Hence, these two negations (*not dead*, *not alive*) should always be viewed as completely different.

The above hypotheses were tested in Experiment 1c, which used longer stimuli, each over multiple sentences that use the antonym pairs from Experiments 1a and 1b within a context, to ensure readers can comprehend such scenarios. If this were the case, then it should be possible to conduct further research using these stimuli within an online study to detect the differences in processing unbounded and bounded concepts.

Experiment 1C: Interpretation of Boundedness in Extended Contexts

The aim of Experiment 1c was to test whether the manipulation of boundedness was interpreted similarly to Experiment 1b when the negated antonyms were placed within extended contexts. This addressed a weakness of Experiment 1b, where the negations were presented without context. As previously discussed in the Literature Review, context has been shown to be an important factor during negation interpretation (e.g. Anderson et al., 2010; Beltran et al., 2008; Nieuwland & Kuperberg, 2008). In Experiment 1c, therefore, we tested whether readers were sensitive to boundedness when interpreting negation within an extended context. Secondly, Experiment 1c investigated how readers interpret conflict between multiple negated antonyms. Passages of text either features the same negated antonym (repetition), two negated antonyms (incongruent), or two antonyms with only one negated (complementary). Participants provided similarity ratings between the two antonym usages in each passage. From the results of Experiment 1b, it was predicted that boundedness would moderate how participants interpreted conflict between two antonyms. The results provide clear evidence for how participants interpret bounded and unbounded negation when assessing text offline.

The use of context has already been a key variable in the investigation of negation interpretation. As noted in the literature review, participants are able to more easily and quickly interpret negation when the negated sentence has been placed within a context that supports the use of negation. For instance, Glenberg et al. (1999) found the sentence: *the couch was not black* to be rapidly processed when presented within

the context a consumer seeking a particular colour of sofa. This is compared to the wealth of data showing negation is always processed slower than affirmative language when presented without a context (Chase & Clark, 1971; Clark & Chase, 1972; Just & Clark, 1973; Just & MacDonald, 1989).

Wason (1965) suggested negation is only processed similarly to affirmation when provided with a motivated context due to the function of negation. Negated propositions, such as *the train is not late*, are structurally more complicated than affirmative equivalents, such as *the train is early*. The use of negation, therefore, is inefficient unless there is pragmatic motivation for the use of negation. Motivation for the example above could be that the train is normally *late*; therefore, the negation is used to deny an expected outcome. Furthermore, Givon (1978) highlighted the fact that negation is inherently more ambiguous than affirmation, as it is commonly used to denote an absence. *The juice is in the fridge* allows the reader to instantiate a direct representation of events; whereas *the juice is not in the fridge* does not (one does not know where *the juice* is), and is, therefore, less informative. Context is needed, therefore, to constrain possibilities of where the juice is, in order for the communicator to correctly interpret discourse. From this viewpoint, it is unsurprising that there is a wealth of research indicating contextual factors have a profound effect on how negation is interpreted. Indeed, it is from this viewpoint that Dynamic Pragmatic theory has sought to explain negation processing, by considering the wealth of pragmatic and contextual variables that can allow for efficient understanding of negation.

Further support for the impact of context comes from Grice's (1975) cooperative principle, a requirement for effective communication, which posits that speakers are motivated to produce truthful, relevant and informative utterances when using language. As described above, this is not necessarily the case with negation, at least out of context, due to the inherent ambiguity of negated sentences. It can be argued that negation meets the cooperative principle when used to reverse an expectation or incorrect assertion, allowing for more efficient processing of negation in this scenario. In Experiment 1b, it could be interpreted that unbounded negation is more likely to require this sort of context in order to be understood efficiently. *Not bad* does not

necessarily mean *good*, and is therefore inherently ambiguous, as there are multiple alternative states. Bounded negation, lacks this ambiguity, as there is only one alternative state to interpret, *not dead* can only mean *alive,* meaning it will always be informative. Verbal politeness is one context where unbounded negation has been shown to have contextual motivation. Negating an unbounded antonym can allow communicators to appear more polite. For example, *the food was not bad*, does not necessarily mean the food was *good*, but is certainly politer than referring to the *food* as *bad* (Colston, 1999; Brown & Levinson. 1987). This allows speakers to communicate in a socially positive manner.

Giora's (2006) review in support of the Dynamic Pragmatic theory of negation processing commented on other contexts that allow for felicitous use of negation. As well as denial, negation can also be used in a host of situations in order to denote a non-literal interpretation of events. For instance, in the phrase *the game has not started yet and he has got 2 goals already*, the negation of *started* is to show that the game has *barely started*, a non-literal statement provided to draw the readers' focus to the time aspect of the event. While context can be a key pragmatic cue in the typical processing of negation, Experiment 1b and that of Paradis and Willners (2006) also show boundedness was another variable that can be used to make negation informative and easy to comprehend.

Previous research has shown the importance of exploring negation within context, due to its profound effect on how readers interpret negation. In Experiment 1c, therefore, the 36 bounded and 36 unbounded antonyms from Experiment 1b were placed into passages of text to test how they were interpreted. In line with previous work on boundedness, including Experiment 1b, it was still predicted that bounded negation would be interpreted as its antonym, the only possible alternative, while unbounded negation would be interpreted as having more than one alternative state. This latter hypothesis was motivated by the notion that negation is not always used to denote a clear opposite state, although this is the case in bounded negation.

In order to investigate negation interpretation within context, the passages each feature two antonym usages, with negation and antonym ordering manipulated, resulting in three passage types (see Table 2.4 for examples). Participants were asked

to provide ratings for how similar they considered the two antonym usages to be. From this, it was possible to explore how equivalent bounded and unbounded negations are to their antonyms within contextual passages that license their usage.

In the repetition condition, the same antonym was featured twice, and negated both times (e.g. *not dead– not dead, not late – not late*). This acted as a control condition with both negations were a direct repetition of the other. It was predicted, therefore, that there would be no differences in similarity ratings across the variable of boundedness.

In the incongruent condition, both antonyms were used, with both negated (e.g. *not dead-not alive, not late – not early*). In this condition, a difference in similarity ratings dependent on the boundedness of the negated antonyms was predicted. It was predicted that readers would rate bounded incongruent negations as being less similar than unbounded. In the bounded case, negations can only be interpreted as one state, the other antonym, so *not dead* is interpreted as *alive* and *not alive* is interpreted as *dead*. As these are two mutually exclusive states, participants were expected to rate them as maximally different from each other. In the unbounded case, both negations share semantic overlap, as they each refer to multiple states. *Not late* can be interpreted as *early* and *on time*, while *not early* can be interpreted as *late* and *on time*. As they share semantic overlap, it was predicted that participants would rate them as more similar than items in the bounded incongruent condition.

In the complementary condition, both antonyms were used, but only the second usage was negated (e.g. *alive – not dead*, *early – not late*). It was predicted that bounded complementary passages would be rated as more similar than unbounded complementary passages. In the bounded case, the negation is unambiguously referring to the previous affirmative state, *not alive* means *dead*. It was predicted, therefore, that maximally similar ratings for this condition, due to the semantic equivalence between the two antonym usages. This semantic equivalence is not present in the unbounded complementary condition, as the negation is ambiguous, and could refer to other states besides the state previously mentioned. *Not late* could mean *on time* as well as the previously mentioned *early*. It was predicted, therefore, that there would be lower similarity ratings in the unbounded complementary

condition than the bounded complementary condition. This condition acted as replication of Experiment 1b within a passage context, as the antonym-negation combinations were identical.

In summary, the aim of Experiment 1c was to investigate how readers comprehend the bounded and unbounded stimuli when opposed and placed within a supporting context. The specific context, in this case, was a passage of text featuring two antonym usages, from two separate characters. The two main predictions were that: 1) In the incongruent condition, the bounded statements will be rated as more different than unbounded. 2) In the complementary condition, the bounded statements will be rated as more similar.

Experiment 1C: Methodology

Participants

Thirty-six participants (18 females) with a mean age of 24.44 (range 18-45) from the University of Southampton took part in exchange for course credits or a small cash payment (£6 /hour). All participants were native English speakers. Participants who took part in this study had not taken part in Experiment 1a or 1b and were excluded from subsequent experiments.

Design and Materials

The 72 pairs of antonyms from Experiment 1a, which had been categorized in terms of boundedness according to the results of Experiment 1b were placed within passage contexts. Within these contexts, the antonyms were used twice, each time from a different character in the scenario. Typically, the stimuli featured one or two context sentences followed by the first character's antonym usage, followed by the second character's antonym usage and then a wrap-up sentence.

The boundedness of the antonyms (bounded vs. unbounded) and the passage type (repetition vs. incongruent vs. complementary) were manipulated within a 2 x 3 experimental design. Six lists were created, with all 72 bounded and unbounded passages each. For each item, passage type was rotated according to a Latin square design, as well as antonym order. For example, in the incongruent condition, one list

contained *not dead-not alive* and the other *not alive-not dead*, resulting in six types of each passage. The dependent variable was participants' similarity rating on a scale of 1-7 (1 being "*completely identical*" and 7 being "*completely different*"). All six conditions can be seen in Table 2.4.

Procedure

Participants took part in the study by completing an online survey, distributed through the University of Southampton's '*efolio research'* service. Participants were instructed that they would be taking part in a study looking into the semantic comprehension of different scenarios. As mentioned above, these scenarios usually featured two characters each giving an opinion. Participants were not informed of any other theoretical motivations for this experiment until a debriefing statement at the end of the questionnaire. They were presented with the 72 different scenarios as described above. Participants were asked to evaluate the similarity of the utterances through the question *How similar was the (character one)'s opinion to (character two)*? Participants made this judgment on a scale of 1-7, with 1 being "*completely identical*" and 7 being "*completely different*". The stimuli were presented in six blocks of 12 pairs, which participants finished in one session, taking between 30-45 minutes to complete in total.

Table 2.4. Examples of bounded repetition, incongruent, complementary and unbounded repetition, incongruent and complementary stimuli passages.

Region of Interest	Text
Bounded Context	Rushing into the emergency room, the doctor and the nurse were talking about one of their cases.
Repetition	The doctor clearly stated that the patient was **not alive**. The nurse declared that the patient was **not alive** and noted it down in her paper work.
Incongruent	The doctor clearly stated that the patient was **not alive**. The nurse declared that the patient was **not dead** and noted it down in her paper work.
Complementary	The doctor clearly stated that the patient was **alive**.

	The nurse declared that the patient was **not dead** and noted it down in her paper work.
Wrap-Up Sentence	Great care was taken to regularly check the condition of all the patients.
Unbounded Context	The boss was checking his new employee's attendance record with his secretary.
Repetition	The boss was quite sure that the employee was **not late**. Following her orders, the secretary noted in her records that the employee was **not late** for work.
Incongruent	The boss was quite sure that the employee was **not late**. Following her orders, the secretary noted in her records that the employee was **not early** for work.
Complementary	The boss was quite sure that the employee was **late**. Following her orders, the secretary noted in her records that the employee was **not early** for work
Wrap-Up Sentence	It was the secretary's job to maintain employee records.

Experiment 1C: Results

Analyses

All 2592 responses were collated and the average resemblance scores were calculated by averaging each item's resemblance rating across both orderings of antonyms. Scores were divided into six conditions depending on their boundedness and passage type. The averages of the ratings by participants are shown in Table 2.5. Linear mixed effects models (LMEs) were constructed using the lme4 package (Bates, Maechler & Bolker, 2012) in R (R Development Core Team, 2013). Passage type and boundedness were treated as fixed factors, and an interaction term was included. The bounded repetition condition was considered the baseline. Items and subjects were treated as random crossed factors. Additional treatment contrasts were programmed to test for differences between the incongruent and the complementary conditions across boundedness.

Similarity Rating Scores

There was a significant interaction between boundedness and passage type on participants' similarity ratings for incongruent (b = 2.20, t = 16.44) and complementary passages (b = 1.09, t = 8.24). Planned contrasts showed that each bounded condition was rated significantly differently from its unbounded counterpart. Participants rated the incongruent unbounded antonym pairs as being more semantically similar to each other (M = 4.25, SD = 1.53) than bounded incongruent antonym pairs (M = 5.83, SD = 1.35, t = -16.46). For example, *not late* was rated as being more similar to *not early* than *not dead* is to *not alive*. This was in line with the prediction that negated bounded items refer to their antonym, and negated unbounded items unambiguously do not. Participants rated unbounded complementary antonym pairs (M = 3.28, SD = 1.28) as being less similar to each other than bounded incongruent antonym pairs (M = 1.77, SD = 1.49, t = 17.23). For example, *not late* was rated as being less similar to *early* than *not dead* is to *alive*. Even the repetition of an unbounded negated antonym (M = 1.88, SD = 1.44) was rated as significantly (t = 4.25) less similar than bounded repetitions (M = 1.47, SD = 1.15). Effectively, *not late* was rated as being less similar to *not late* than *not dead* is to *not dead*. This suggests that even without contrast, unbounded negation referred to a more ambiguous set of states than bounded negation. This set of results indicated that the boundedness manipulation was interpreted as expected. Bounded negation was seen as synonymous with its antonym, whereas unbounded negation was not.

Table 2.5. Mean similarity ratings in Experiment 1c.

Condition	Mean	SD
Bounded-Both Negated-Same	1.47	1.15
Unbounded-Both Negated-Same	1.88	1.44
Bounded-Both Negated-Different	5.83	1.35
Unbounded-Both Negated-Different	4.26	1.53
Bounded- One Negated-Different	1.77	1.49
Unbounded- One	3.28	1.38

Negated-Different

Experiment 1C: Discussion

Experiment 1c aimed to investigate how readers comprehend the bounded and unbounded stimuli when placed within a supporting context. Experiment 1c replicated the results of Experiment 1b as it was found, in the complementary condition, that unbounded negations were rated as being less similar to their antonym than bounded negation. This also replicates the findings of other negation studies (Fraenkel & Schul, 2008; Paradis & Willners, 2006) in indicating that when bounded concepts are negated, they can only reasonably be referring to their antonym. This is compared to unbounded items where the negation does not necessarily instantiate a representation of the antonym, as it is ambiguous. This conclusion can also be drawn from the results for the incongruent conditions. While one bounded negation is more semantically equivalent to its antonym than an unbounded negation, two unbounded negations share more semantic equivalence than two bounded negations. As bounded negations refer informatively to their antonym, two bounded negations were rated as sharing no semantic overlap. As unbounded negation is ambiguous, and could refer to multiple states, there is semantic overlap in terms of these multiple states between two unbounded negations. For example, *not late* and *not early* both have the same alternative state of *on time* hence they share semantic overlap. These results provide very clear evidence that readers are sensitive to boundedness when providing offline interpretation ratings of negation.

These results provide evidence that allows us to make several, theoretically motivated hypotheses about how readers would read these passages on a word-by-word level. It would be expected for readers to read bounded complementary passages as easily as the repetition passages. As the negation is semantically equivalent to the previously mentioned antonym, it should not be effortful in terms of processing to integrate these two representations into a stable discourse model of the text. Unbounded complementary passages, on the other hand, should be slower to integrate, as the negation does not share semantic equivalence with the previously

mentioned antonym. Integrating this ambiguous negation with the previously antonym, therefore, would be slower in the unbounded case. It would be reasonable, therefore, to predict more disruption to processing in the unbounded case, from the point of reading the second antonym, compared to the bounded case.

In terms of the incongruent passages, these offline data and notions of boundedness suggest the bounded incongruent passage is not possible to integrate into a unified representation, as the two negations both unambiguously refer to mutually exclusive states. This is compared to the unbounded incongruent condition, where the two negations do share semantic overlap; suggesting readers would not suffer the same magnitude of disruption integrating these two representations. It would be reasonable, therefore, to predict that readers would not be able to return to normal reading in the bounded incongruent condition. As it is not possible to integrate two mutually exclusive states, as shown in Experiments 1b and 1c, readers should not be able to return to normal reading. This is compared to the unbounded case, where it is possible to integrate the two negations into a single representation, as they share some semantic similarity, according to the results here. While there may be some processing delays in this unbounded case, as integration occurs, it should not be to the level predicted in the bounded case, where no successful integration is possible.

The bounded repetition passages were rated as being more similar than the unbounded repetition passages. As expected, both repetition conditions elicited high levels of similarity. The difference found indicated that unbounded repetitions were considered less similar than bounded repetitions. This small difference appears to reflect the fact that unbounded utterances are inherently more ambiguous than bounded utterances. For instance, to say someone is *tall* can be placed anywhere at the upper pole of a *tall-short* continuum and is more subjective than asserting that someone is *dead* (Paradis & Willners, 2006). Furthermore, there is evidence suggesting quantity-denoting expressions, such as *tall/short*, require context or an implicature on the part of the reader in order to be interpreted (Kennedy & McNally, 2005). For instance, if one is told to *pick up the tall glass*, the reader must reason there is a *glass* taller than the others (Breheny, Ferguson & Katsos, 2013; Grodner &

Sedivy, 2011; Huang & Arnold, 2017; Sedivy, 2003). This indicates that unbounded items, which have multiple states and therefore often refer to quantity distributions, are inherently ambiguous, with limited evidence provided by the offline ratings for the repetition passages. This effect is, however, very small, making it difficult to make any online predictions about this difference. One prediction, however, could be that unbounded items will always be processed more slowly than bounded items, due to the higher level of similarity between bounded repetitions, compared to unbounded repetitions.

Summary

Through the preceding series of linguistic tests, a set of 36 bounded and unbounded canonical antonym pairs have been established. Furthermore, it has been shown that readers were sensitive to the linguistic operator of boundedness when interpreting these negated antonyms when making offline interpretation judgments. Experiment 1a was an antonym elicitation task. The results of this experiment provided 36 bounded and unbounded antonym pairs that did not differ in the strength of their antonymic relationship. In Experiment 1b, these antonym pairs were placed into sentence pairs, with one presented in its affirmative form, and one negated. The results of this experiment found readers were sensitive to the linguistic operator of boundedness when making offline-rating judgments about negated sentences. Specifically, readers rated bounded negations as being more similar to their antonym than unbounded negations. In Experiment 1c, this effect was replicated within passage contexts. Furthermore, it was found that two bounded negations were considered less similar than two unbounded negations. The findings of Experiments 1b and 1c conform to the predictions made based on our previous knowledge of boundedness. Specifically, that bounded concepts only feature two categorical states, meaning bounded negation must refer to its antonym. In contrast, unbounded concepts feature more than two states, meaning unbounded negation is not necessarily interpreted as referring to its antonym. In the offline ratings provided here, it was clear readers were sensitive to the linguistic operator of boundedness when interpreting negation. These results suggest that Dynamic Pragmatic account of negation, where the processing and interpretation of negation is the result of multiple

contextual and pragmatic factors, must also consider boundedness as one of these factors.

Within this chapter, a series of empirical tests have validated the boundedness manipulation and confirmed readers were sensitive to this categorization when interpreting negation within a passage context. Experiments 1a, 1b and 1c have established a set of bounded and unbounded antonym pairs, which have been tested using offline-rating methods. The key, original conclusion of these experiments comes from Experiment 1c, where it was found that readers were sensitive to the linguistic operator of boundedness during offline interpretation. Experiment 1a served as stimulus development, while Experiment 1b can be considered a replication of past work on boundedness, using a wider set of stimuli that do not just include adjectives. It is possible that task effects are driving the effects presented here, where readers are forced to focus on the two antonyms present in the passages, leading to a level of consideration that would not be taken during natural processing. In order to test how these are being processed as participants move incrementally through text, a methodology that is capable of conveying the underlying moment to moment cognitive processing during reading is required, such as eye tracking (see Liversedge & Findlay, 2000; Rayner, 1998). Experiment 2 will use this methodology to investigate how readers are processing negated concepts incrementally, as they read them, rather than taking ratings once readers have finished comprehending the text.

Chapter 3

An Eye Movement Investigation of the Processing of Negated Bounded and Unbounded Expressions During Reading

Current literature suggests that the processing of negated text is affected by a number of linguistic and pragmatic constraints (Giora, 2006; Tian et al. 2010; 2016). Specifically, when negation is unambiguous and has only one alternative representation, it can be rapidly instantiated. This is compared to when negation is ambiguous, in that it has many alternative states, where it is found that negation is more slowly instantiated into discourse, as readers deal with this ambiguity (Anderson, Huette, Matlock & Spivey, 2010; Du, Liu, Zhang, Hitchman & Lin, 2014). Chapter 3 explores how the semantic configuration of concepts affects the reading of negation, using an eye movement and reading methodology.

The boundedness hypothesis suggests that negated mental representations are sensitive to the semantic configuration of the negated entity (Paradis & Willners, 2006). Bounded entities are categorical; only one state is possible so, when negated, a bounded entity must be interpreted as its antonym (*not dead=alive).* Unbounded entities possess a scalar ontology, with many states in between the antonyms; when negated they are ambiguous and can refer to multiple states (*not wide≠narrow).* Experiments 1a-c in this thesis also evidenced that readers are sensitive to this categorization when assessing their ultimate interpretation of text using offline forced rating scores. Within Chapter Three the online interpretation of bounded and unbounded negation is investigated. In Experiment 2, participants read passages with two statements from different characters describing a bounded/unbounded entity (taken from Experiment 1c). This represented the first investigation of boundedness effects in reading. Unlike most of the previous negation literature, Experiment 2 utilized eye tracking during passage reading. Eye tracking whilst reading is a non-invasive measure, with reading times and regression analyses providing an objective, temporally sensitive measure of lexical, syntactic and semantic processing (Frazier & Rayner, 1982; Inhoff & Rayner, 1986; Liversedge & Findlay, 2000; Rayner, 1998, 2009). In the next section, predictions for the reading of these passages are discussed.

It will be shown that clear predictions can be drawn from the results of Experiment 1c, as well other findings from the negation literature.

Introduction

Within Experiment 2, the influence of boundedness on online processing of negation during reading is evaluated. Specifically, whether bounded items, such as *dead/alive,* can be rapidly processed when negated, as they denote a clear representation in which the negation carries the same meaning as the antonym. Moreover, the processing of these bounded items is compared with unbounded items, such as *wide/narrow,* for which negation does not imply the antonym, but has an underspecified meaning consistent with a range of alternative states. Experiment 2 aimed to replicate and extend the findings of Experiment 1b and 1c, by testing whether readers are sensitive to this linguistic operator during incremental interpretation. By measuring eye movements, it could be seen whether readers considered the semantic configuration of negated items as they are being read.

Incremental interpretation describes the notion that a reader adapts their interpretation of text on a word-by-word basis rather than delaying semantic interpretation to the end of text units (Altmann & Steedman, 1988; Altmann & Kamide, 1999). Support for an incremental interpretation account stems from findings that verb-noun dependencies that are many words apart (unbounded dependencies) are processed as implausible immediately (Traxler & Pickering, 1996). For instance, in sentence 1 readers exhibited longer first fixation durations and first pass reading measured on the verb "*shot"* when the noun *garage* is used due to the implausibility (one cannot conceivably shoot someone with a garage no matter how heartless they are).

1. *That is the very small pistol/garage with which the heartless killer shot the hapless man.*

The fact this occurred immediately upon reading the word that makes the reader's interpretation implausible indicated that readers were updating their discourse representation on a word-by-word basis. The rapid plausibility effect, as evidence for incremental processing, has been replicated consistently (Clifton, 1993;

Stowe, 1989; Trueswell, Tanenhaus & Garnsey, 1994) using eye tracking (Joseph, et al., 2009; Rayner, et al., 2004; Warren & McConnell, 2007) and with ERPs (Garnsey, Tanenhaus & Chapman, 1989; Nieuwland & Kuperberg, 2008; Nieuwland & van Berkum, 2006). This suggests that readers take into account many linguistic variables when reading. The aim of Experiment 2, therefore, was to investigate whether boundedness is one of these. Within Experiment 2, inconsistency effects during reading of text were considered as an index of processing difficulty on the part of the reader attempting to comprehend the passages of text presented to them. Inconsistency effects are characterized by longer reading times and more regressive saccades back into the text (Joseph et al., 2008; Rayner et al., 2004; Warren & McConnell, 2007; Warren, McConnell & Rayner, 2008).

As previously discussed, the boundedness hypothesis (Paradis & Willners, 2006) suggests negation is not a uniform process. Instead, the processing of negation, and its resultant representation, may be affected by the semantic ontology of the negated entity. In the case of bounded negation, comprehenders can only instantiate one, unambiguous representation, as only two states exist within the concepts' semantic configuration (e.g. *dead-alive)*. Due to the transparency of a bounded negation, the processing of negation may involve the selection of only one alternative, and so the instantiation of this representation may proceed simply and rapidly. For unbounded negation, however, where negation is underspecified, and there are many possible alternative states (e.g. *wide-narrow* and all states in between), the processing of negation may be more complex and so less rapid.

Experiment 2: On-line Processing of Bounded and Unbounded Negation

In summary, the aim of the present study was to examine whether negation was processed differentially online during reading as the result of the boundedness of the negated element. In contrast to previous studies, in Experiment 2, effects of boundedness were examined directly rather than relying on context to manipulate the availability of alternative interpretations. Furthermore, the present study used measures of eye movements to reveal whether effects of boundedness occur online

during normal reading. To do this, participants read the passages from Experiment 1c while their eye movements were recorded, in order to measure how they read the passages. The passages were also split into eight regions of interest, in order to fully investigate how these passages were read (Table 3.1). There were three passage types. First, passages with repeated negation featured the use of one member of the antonym pair twice in its negated form (e.g. *the doctor said that the patient was not dead*, followed by *the nurse said that the patient was not dead*) and acted as a control condition. Second, incongruent passages featured both antonyms in their negated form (e.g. *not dead – not alive).* Finally, complementary passages featured both antonyms, but only the second was negated (*e.g. dead – not alive)*. Experiment 2 allows the investigation of the extent to which the incongruent and complementary passages produced disruption to the normal processing of text relative to the control condition.

Hypotheses

Experiments 1a-c showed that readers are sensitive to boundedness, when they are asked to make off-line judgments based on a final interpretation of text. These findings are important in demonstrating that readers are sensitive to boundedness, but do not show if this is processed automatically during the on-line processing of text. In Experiment 2, the nature and time course of such processing was investigated when participants read sentences containing negated bounded and unbounded expressions.

It is important to note that under a two-step theory of negation, no effects of boundedness would be predicted. Instead, it would have been predicted that there would always be a delay in reading negation. This would be due to the fact that negation always requires two steps in order to be successfully comprehended, with this second step (invalidating an affirmative representation) always taking a longer amount of time. Instead, the predictions presented here were with the expectation of a moderating influence of boundedness on the reading of negated events. In this manner, the predictions are more appropriate when considered within a Dynamic Pragmatic account. That is to say, the ambiguity of a negation (as indexed by a

negated element's boundedness) would affect how readers interpreted it.

The use of eye movement methodology ensures that the immediacy and more general time course of any disruption to processing can be investigated in Experiment 2. Longer first fixation durations/gaze durations have been reported for words that are semantically or contextually anomalous (Braze, Shankweiler, Ni & Palumbo, 2002; Murray & Rowan, 1998; Traxler, Foss, Seely, Kaup & Morris, 2000). It, therefore, seemed likely that disruption caused by detection of a semantic incongruity might be observed in these measures. An increase in regressions back into the text when processing difficulty occurred at the target region was also expected (Frazier & Rayner, 1982; Levy, Bicknell, Slattery & Rayner, 2009; Rayner, Chace, Slattery & Ashby, 2006). As bounded negation unambiguously represents a single state, instantiation of a representation of that state should be quite immediate (Du, Liu, Zhang, Hitchman and Lin, 2014). Consequently, it was expected that any bounded anomaly would be rapidly detected when readers first fixated the target word in the incongruent condition. Furthermore, as unbounded negation is inherently ambiguous, offering more than a single state, the instantiation of a representation of its meaning has been argued to have a slower time course (Fraenkel & Schul, 2008; Paradis & Willners, 2006). Disruption, therefore, was expected to occur later in the eye movement record, both in regions downstream from the target word, and in terms of later measures of processing for unbounded relative to bounded stimuli. To be clear, more immediate and more pronounced effects of disruption to eye movements were expected for the bounded relative to the unbounded stimuli.

Repetition Passages

In the case of the repetition condition, despite a small difference in offline ratings in Experiment 1c, no effects of boundedness were predicted, as both passages feature the repetition of a negation. As such, being the least cognitively demanding of the conditions, it would act as an baseline condition to demonstrate eye movement behaviour during processing of a negation that is acceptable and typical within its context, to the point that it is a repetition. This condition was, therefore, expected to yield the fastest reading times, regardless of boundedness.

Bounded Incongruent Passages

For the bounded conditions, differences in eye movement behaviour were expected between the complementary and incongruent passages. For the incongruent passages, off-line data (Experiment 1c) showed these antonyms were considered the least semantically similar due to the incongruent sentence signalling to the reader two states that are mutually exclusive, and therefore, these states cannot be integrated into a single meaningful representation (Ladusaw, 1996; Paradis & Willners, 2006). Specifically, the first antonym usage informs the reader of one categorical state (*not dead = alive)*. The incongruent sentence signals to the reader a state that is mutually exclusive of the previous (*not alive = dead*), and the two states cannot be integrated into a single representation. It was, therefore, predicted that there would be considerable disruption to processing for these sentences relative to the repetition condition. As bounded negation unambiguously represents a single state, instantiation of a representation of that state should be quite immediate (Du, Liu, Zhang, Hitchman & Lin, 2014). Consequently, it was expected that any bounded anomaly would be rapidly detected when readers first fixate the target word in the incongruent condition. Note also that these predictions are consistent with the results from the off-line similarity investigation (Experiment 1c; high similarity = 1, low similarity = 7) where bounded incongruent antonyms were rated as much less similar to their antonym than any other condition (similarity = 5.83). Readers would, therefore, experience disruption with a fairly immediate time course that would continue throughout the post target region of the incongruent sentence and throughout the wrap-up sentence to the end of the passage.

Bounded Complementary Passages

For the complementary passages, it was anticipated that readers would have very little difficulty integrating the negation with the antonym since the two states described are entirely consistent (e.g., *not dead = alive*). For this reason, little difference in eye movement behaviour was predicted between the bounded complementary and the repetition conditions (and consequently, a substantial difference between the bounded complementary and bounded incongruent conditions). This prediction was consistent with the results from the off-line similarity investigation (Experiment 1c) where a bounded complementary negation

and its antonym were rated as similar (similarity = 1.77), and almost comparably similar to a repetition (similarity = 1.47), and much more similar than incongruent antonyms.

Unbounded Incongruent Passages

In Experiment 1c, comparable similarity ratings were obtained for the unbounded complementary (similarity = 3.28) and the unbounded incongruent items (similarity = 4.25). Neither of these types of stimuli was considered to be as dissimilar as the bounded incongruent items. This is very likely due to the fact that these antonyms and their negations refer to states that are not mutually exclusive, and therefore, it is possible establish a degree of similarity between them. The first antonym usage informs the reader of at least two states (*not early = late* or *on time)*, as does the incongruent sentence (*not late = early* or *on time*). The two negations can, therefore, be integrated into a coherent interpretation, as there is at least one plausible state that could be interpreted from the text. Presumably, while cognitive processing effort was required to establish that a shared interpretative state is possible, participants were able establish the possibility of a coherent interpretation and their similarity scores reflect this. This was not expected to disrupt reading to the magnitude seen in the bounded incongruent condition, where the two bounded negations demand that the reader detect and attempt to rectify an anomaly within the text. As such, disruption was expected to extend through a shorter time course than in the bounded case, i.e. not disruption past the post-target region, as readers will have integrated the two unbounded negations into a unified representation by the end of reading the passage, unlike in the bounded incongruent condition.

Unbounded Complementary Passages

As previously stated, the states denoted within unbounded complementary passages were rated as being of a similar comparability to those within the incongruent passages. This motivated a predicted pattern of effects, such that reading times would be fastest for the baseline repetition condition, with increased and comparable disruption for the complementary and incongruent conditions. In the

case of unbounded complementary passages, the negation (*not late*, i.e., *early* or *on time*) offers a shared state with *early*, though not unambiguously so. Thus, again, at a relatively minor cost (comparable to that observed for the unbounded incongruent items), participants should be able to establish a coherent representation of meaning. Furthermore, in Experiment 1b and 1c, participants rated unbounded negation as less semantically similar to its antonym than bounded negation. This lack of semantic equivalence should result in more processing difficulty compared to the bounded complementary condition, with disruption possible past the target word, as readers infer the ambiguous negation is felicitous with the first antonym use. Furthermore, as unbounded negation is ambiguous, it was predicted that the immediacy of any disruption would be delayed to later eye movement measures from the target word (the second antonym).

Markedness

The markedness of negated expressions, that is, the frequency/regularity with which each antonym is negated in typical language use, might also be an important consideration in the present experiment. For example, Fraenkel and Schul (2008) found that bounded items are rated as more similar to their antonym than unbounded negations, but the similarity of bounded and unbounded expressions is also influenced by markedness. An unmarked expression is the usual, often positive member of an antonymic pair (Hartmann & Stork, 1972). Unmarked expressions are also considered to be more neutral, for instance "*how tall was the ladder?*" has been suggested to carry no implication. This is compared to "*how short is the ladder?*" which constrains readers to a pragmatic inference that the ladder is shorter than usual (Battistella, 1996). In this case the unmarked member would be *tall* and the marked would be *short*. Fraenkel and Schul found that *not good* is considered more synonymous with *bad*, than *not bad* with *good.* In order to control for any effect of markedness, antonym order of passages was counterbalanced so participants were presented with all possible antonym orders. This was in order to analyse whether there was an interactive effect of markedness on the processing of the negated passages. Specifically, whether unbounded complementary passages where the second (negated) utterance is unmarked were more quickly assimilated into a

reader's discourse representation, as the two utterances more clearly resemble each other.

Summary

In summary, the aim of this study was to investigate whether readers are sensitive to the linguistic operator of boundedness during on-line sentence processing. The predictions presented here are clearly motivated given the findings of Experiments 1b and 1c, as well as findings from the Dynamic Pragmatic account of negation processing, which posits that only unambiguous negation can be processed rapidly. Within this account, boundedness is a functional constraint that can be placed upon negation interpretation. For example, if readers are sensitive to boundedness during reading, then bounded negation should constrain readers to instantiate a single, unambiguous representation (e.g. *not dead = alive*). Unbounded negation, on the other hand, applies less constraint, due to its ambiguity. Thus, it was predicted that bounded negation would be easily integrated with its antonym, but cannot be integrated with its negated antonym. This is compared to unbounded negation, which should not be easily integrated with its antonym, as there is a lack of semantic equivalence seen in the bounded case (e.g. *not late* does not necessarily mean *early*). Unbounded negation should, however, be integrated with its negated antonym, as both point to a possible alternative state (*not late* and *not early* can be integrated into the state of *on time*). In Experiment 2, eye movement measures were used to indicate whether readers are sensitive to boundedness during reading and assess the timecourse of processing this linguistic information.

Experiment 2: Methodology

Participants

Seventy-two participants (59 females) with a mean age of 20 years (range = 18-46 years) from the University of Southampton took part for course credit or a small cash payment (£6/hour). All participants were native English speakers and reported normal or corrected to normal vision and had no known reading difficulties.

Table 3.1. Regions of interest in the (i) bounded and (ii) unbounded repetition, incongruent and complementary conditions.

Region of Interest	Text
(i) Licensing Context	Rushing into the emergency room, the doctor and the nurse were talking about one of their cases.
First Antonym Use	The doctor stated clearly that the patient was | (not) | **alive**.|
Repetition Sentence	| The nurse declared that the patient was | not | **alive**| and noted it down in her paperwork. |
Incongruent Sentence	| The nurse declared that the patient was | not | **dead**| and noted it down in her paperwork. |
Complementary Sentence	| The nurse declared that the patient was | not | **dead**| and noted it down in her paperwork. |
Wrap-Up Sentence	| Great care was taken to regularly check the condition of all the patients. |
(ii) Licensing Context	The boss was checking his new employee's attendance record with his secretary.
First Antonym Use	| The boss was quite sure the employee was | (not) | **early**. |
Repetition Sentence	| Following her orders, the secretary noted in her records that the employee was | not | **early**| for work today. |
Incongruent Sentence	| Following her orders, the secretary noted in her records that the employee was | not | **late**| for work today. |
Complementary Sentence	| Following her orders, the secretary noted in her records that the employee was | not | **late**| for work today. |
Wrap-Up Sentence	| It was the secretary's job to maintain employee records. |

Note. *Eight regions of interest are indicated by vertical lines. Region 1 - the first antonym sentence context. Region 2 - the first negation (not present in complementary condition). Region 3 - the first antonym. Region 4 - the second antonym sentence context. Region 5 - the second negation. Region 6 - the second antonym (the target). Region 7 - the spillover region. Region 8 - a wrap-up sentence.*

Materials and Design

The study used a within-participants design with the factors of boundedness

(bounded, unbounded), passage type (negated repetition, negated incongruent, complementary combination), and markedness (the polarity of the second antonym: positive – *early/alive* vs. negative – *late*/*dead*). See Table 3.1 for examples of the passages used. Passages can be seen in Appendix A.

The 72 passages from Experiment 1c were produced as images, for readers to read. The passages were split into eight regions of analysis (see Results). The passages contained an opening sentence, followed by a verb phrase where a person made an assertion (bounded – *The Doctor stated clearly the patient is (not) dead/alive,* or unbounded – *The boss was quite clear that the new employee was (not) early/late*) that the second antonym contrasted with. The following sentence featured either a repeated, incongruent or complementary statement. Another phrase followed this, which served to capture any spill over effects, and the passages finished with a wrap-up sentence. Items were divided into 12 stimulus lists containing all 72 bounded and unbounded stimuli, with markedness and antonym combination counterbalanced over the lists using a Latin square. Each list contained an additional 72 additional filler items that were of similar length to the experimental items. Materials were presented to participants across four to seven lines in double-spaced format. The passage contexts were created to ensure a natural sounding and maximally effective manipulation, as such, it was not possible to match the contexts across boundedness and ensure equal felicity. See Table 3.2 for a summary of lexical characteristics of the bounded and unbounded antonyms.

Table 3.2. Length, frequency and boundedness characteristics of the bounded and unbounded target antonyms.

Condition	Length		Frequency		Boundedness		Prevalence	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Bounded	6.23	1.96	9.81	1.81	1.52	0.44	91.84	9.42
Unbounded	6.00	2.13	9.61	1.41	3.17	0.87	92.88	9.80

Note*. Word frequencies obtained using log values from the English Lexicon Project (Balota et al., 2007). Prevalence reflects antonym elicitation rate from Experiment 1a. Boundedness reflects average similarity score from Experiment 1b (1- completely identical, 7 completely different).*

Procedure

Participants were instructed to read the passages normally and for comprehension. Participant's right eye movements were recorded using an SR Research (Ontario, Canada) Eyelink 1000 eye-tracker (1000 Hz sampling rate), although viewing was binocular. Sentences were displayed on a CRT monitor as black, monospaced Courier font on a grey background. At a viewing distance of 70cm, three characters equalled 1° of visual angle. The participant's head was stabilized using a head/chin rest to minimize movement. At the start of the experiment, participants completed a 9-point calibration procedure with a maximum error of .5 degrees. Participants then completed four practice trials in order to familiarize themselves with the experimental procedure.

At the start of each trial, a fixation cross appeared near the upper left corner of the screen. Once this was fixated, a passage was presented with the first letter replacing the fixation cross. The participant pressed a response key once they finished reading the passage and the passage then disappeared and on 50% of trials was replaced by a yes/no comprehension question. Each participant viewed 72 experimental items and 72 filler items presented in random order. For each participant, the experiment took approximately 60 minutes.

Experiment 2: Results

Short, contiguous fixations were corrected using an automatic procedure; fixations under 80 milliseconds were incorporated into larger fixations within one character, and fixations under 40 milliseconds more than three characters from another fixation, or over 800 milliseconds, were deleted. In addition, trials in which there was track loss or participants appeared not to have completed reading the passage were eliminated (these were calculated by removing trials where two or more adjacent areas had zero first-pass reading times or when tracker loss was noticed by the experimenter). Any regions skipped during first pass reading were excluded from the analyses. These exclusions accounted for 3.4% of the data. Prior to data analysis, data for each eye movement measure that were more than 2.5 standard

deviations from the condition mean for each participant were removed (affecting <1% of dataset). Data loss affected all conditions similarly (i.e. no differences across conditions, all *t*s<1). Across participants, 92% of the comprehension questions were answered correctly with no differences observed across conditions (all *t*s<1).

Analyses

The data were analysed using linear mixed effects models (LMEs) and the lme4 package (Bates, Maechler & Bolker, 2012) in R (R Development Core Team, 2013). Passage type was treated as a fixed factor with the repetition condition as the baseline. A treatment contrast was programmed to test for differences between the incongruent and complementary conditions. Participants and items were treated as crossed random factors (Baayen, 2008; Baayen, Davidson & Bates, 2008). A maximal random model was initially specified for the random factors (Barr, Levy, Scheepers, & Tily, 2013). If a model did not converge, it was reduced by first removing the random effect correlations and then by successively removing the random effects explaining the least variance until the maximal converging model was identified.

In order to maintain equal levels of felicity between bounded and unbounded items, it was necessary that the passages for each type of item were different. Due to content differences across bounded and unbounded passages, separate analyses were conducted for the data sets from each type of stimulus. An important exception to this was the target words. As described previously, the target words were matched across boundedness for lexical characteristics such as length, frequency and antonymy relationship. Furthermore, the target region was always only one word long. For this reason, additional analyses were run for the target region, with the bounded and unbounded datasets combined, to statistically formalize any differences between the bounded and unbounded datasets. Analyses were as above; with boundedness inserted into the models as an interaction term (See Table 3.3) and successive difference contrasts between conditions were run when a significant interaction was found. Interaction analyses were only run on first pass measures (first fixation duration, gaze duration and regressions out), as other measures include fixations into regions of text containing content differences. Furthermore, the differing passage lengths contaminate the measure of total reading time. Longer passages provide

readers with more time to take the opportunity to refixate the target antonym, which could artificially affect total reading time. It was decided, therefore, that total reading time was also not suitable for interaction analyses, due to content differences. In the interaction analysis, as successive difference contrasts were used for the fixed factors, the intercept corresponds to the grand mean and the fixed factor estimate for a categorical factor can be interpreted as the difference between the two conditions.

Regression data were analysed using logistic models. The means and standard deviations of all reading measures across all eight regions can be found in Table 3.4. The regression rates can be found in Table 3.5. Models were originally run with an interaction term for markedness. No interactive effect was found for any of these models, nor did they improve the fit of the models. Data were, therefore, reported from statistical models without this interactive term. This suggests markedness does not have an effect in the online interpretation of negation. The beta values, standard errors and *t/z* values from the models are displayed in Tables 3.4, 3.6 and 3.7 for the bounded and unbounded datasets.

Regions of Interest

Materials were divided into eight regions of interest and analysed as per Table 3.1. Region 1, the first sentence context, was the beginning of the declarative clause that featured the first antonym use and included the beginning of the sentence up until the first negation or, in the case of the complementary condition, the first antonym use. Region 2, the first negation, included the negation of the first antonym; it was, therefore, only available in the incongruent and repetition conditions as the complementary condition presented the first antonym in its affirmative state. Region 3, the first antonym, was the first antonym. Region 4, the second sentence context, was the beginning of the declarative clause that featured the second antonym use and contained text from this clause until the negation of the second antonym. Region 5, the second negation, was the negation of the second antonym (present in all conditions). Region 6 was the second antonym and, therefore, the target region, as it was the earliest point at which any possible inconsistency/anomaly could be detected within each stimulus. Region 7 was the post-target region and consisted of the three

words immediately after the second antonym within the same sentence. Region 8 was a wrap-up region consisting of a final sentence of the passage.

Measures

Three first-pass measures were analysed in order to assess whether the experimental manipulation caused disruption to reading, early in processing. (1) First fixation duration was the duration of the first fixation on a region; (2) First –pass reading time (or Gaze duration when for regions consisting of only one word) was the sum of fixations from the first fixation within a region until a saccade to another region; (3) Regressions out was the probability of a regressive eye movement to reinspect previous regions of text from a region during first-pass reading (fixations made during the initial inspection of text). First fixation duration and first-pass reading time provide measures of early processing (Rayner, Sereno, Morris, Schmauder & Clifton, 1989; Clifton, Staub & Rayner, 2007). As discussed previously, longer first fixation duration/gaze durations, more regressions have been reported for words that are semantically or contextually anomalous (Braze, Shankweiler, Ni & Palumbo, 2002; Murray & Rowan, 1998; Traxler, Foss, Seely, Kaup & Morris, 2000). It, therefore, seemed likely that disruption caused by detection of any semantic anomaly/inconsistency within the stimuli might be observed in these measures.

First fixation duration, first-pass reading time/gaze duration and regressions out measures were, therefore, analysed for regions after readers were expected to detect any anomaly (i.e., region 6, the second antonym) onwards. The LME analyses of these measures can be found in Table 3.3 (interaction analyses) and 3.6.

Three measures of reading were analysed that are typically associated with later disruption to processing. (1) Go-Past Reading Time was the sum of fixations from the first fixation in a region until a saccade was made into a later region of the passage, this included any fixations that were made to re-inspect previous regions. This measure provides an index of later processing, that is, the time readers spent rereading text. (2) Total reading time was the summed duration of all fixations made within a region. As total and go-past reading times include elements of re-inspection in the timecourse of readers moving through the text, these measures reflect later

processes and provide a measure of later disruption associated with processing semantic inconsistency (Liversedge et al., 1998). (3) Regressions in is a measure of the probability with which regressions were made back into a region from a later region of the passage. This measure provides an indication of where within the passage readers spent time re-inspecting text upon experiencing processing difficulty (Rayner et al., 1989; Clifton et al., 2007). As such, regressions in and total reading time were analysed for all regions of the stimuli (with the exception of regressions into the final region, which is not possible in this paradigm), to investigate rereading of the passage upon reaching a semantic inconsistency. As go-past reading times are generally taken to reflect how long it took readers to integrate information from a region with that from previous regions, this measure was analysed for the target region onwards. The go-past reading time LME statistics are shown in Tables 3.6 and 3.7. LME statistics of all other late measures are shown in Table 3.6 (target and post-target regions) and 3.7 (pre-target regions).

First Pass Measures on the Target Region (Interaction Analyses)

Recall that analyses conducted for the target region included the bounded and unbounded dataset together, to test for an interactive effect of boundedness and passage type, as this region offers comparability across the conditions (see Table 3.3). There was no significant interaction between boundedness and passage type on first fixation duration, nor were there any main effects of boundedness or passage type.

Table 3.3. Fixed effect estimates from the linear mixed-effect models for interaction analyses.

	Regressions Out (P)		First Fixation Duration (ms)		Gaze Duration (ms)	
	Estimate	*z* value	Estimate	*t* value	Estimate	*t* value
Repetition (intercept)	-1.48	11.65*	222.00	72.09*	243.42	52.60*
Incongruent	0.26	1.82	3.50	1.38	12.90	3.33*
Complementary	0.05	0.32	4.10	1.63	0.68	0.18
Contrast	0.30	2.15*	4.49	1.28	9.64	1.82
Boundedness	0.01	0.04	1.21	0.49	-2.61	-0.54
Boundedness x Passage type [a]	-0.18	-0.88	1.06	0.21	6.29	0.81
Boundedness x Passage type [b]	0.47	2.35*	-0.77	0.15	-14.48	1.75
Boundedness x	0.29	0.15	0.29	0.06	-7.99	1.05

Passage type [c]

** t>1.96. Incongruent - comparison of repetition and incongruent passages. Complementary - comparison of repetition and complementary passages. Contrast - comparison of complementary and incongruent conditions.* [a] refers to the influence of boundedness on the difference between repetition and incongruent passages. [b] refers to the influence of boundedness on the difference between incongruent and complementary passages. [c] refers to the influence of boundedness on the difference between repetition and complementary passages.

There was a main effect of congruency (across boundedness) such that incongruent passages resulted in longer gaze durations than repetition passages. Gaze durations for complementary passages were not significantly longer than those for repetition passages. This effect was qualified by a marginal interaction (see Figure 3.1) of boundedness and passage type for gaze durations (t = 1.75). Consistent with the predictions made previously for unbounded passages, planned contrasts revealed longer gaze durations for the unbounded incongruent (b = 17.73, t = 3.13) and unbounded complementary (b = 11.39, t = 1.99) conditions compared to the repetition condition. For the bounded passages, gaze durations on the target word in the complementary condition were longer than in the repetition condition (b = 17.24, t = 2.91). There was, however, no significant difference between the bounded incongruent and bounded repetition conditions (b = 9.97, t = 1.68).

There was also a significant interaction of boundedness and passage type on the measure of regressions out of the target region (see Figure 3.2). There were no significant differences in the number of regressions from the target word in the unbounded conditions (all z <1.96). However, for the bounded passages there were more regressions from the target in the incongruent than complementary or repetition conditions (b = 0.30, t = 2.12; b = 0.26, t = 1.82 respectively).

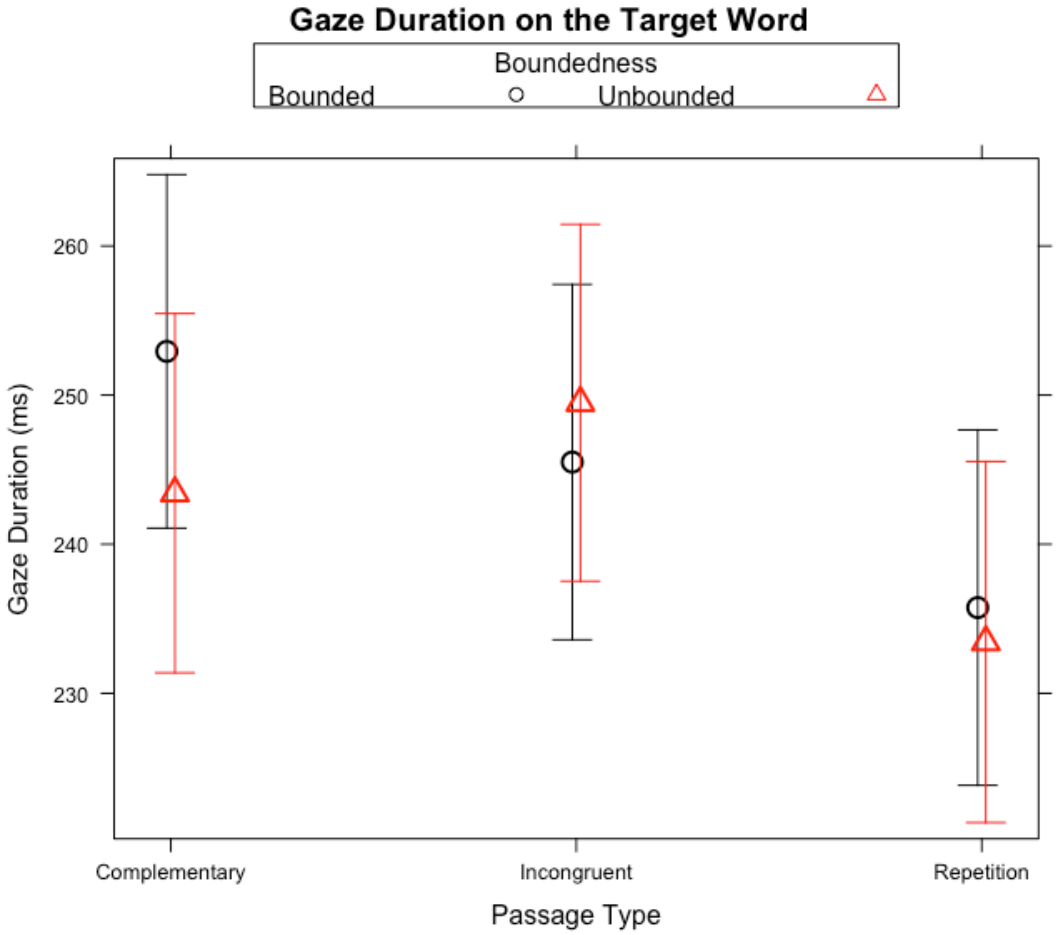

Figure 3.1. Gaze durations on the target region for all conditions. Means and standard error bars.

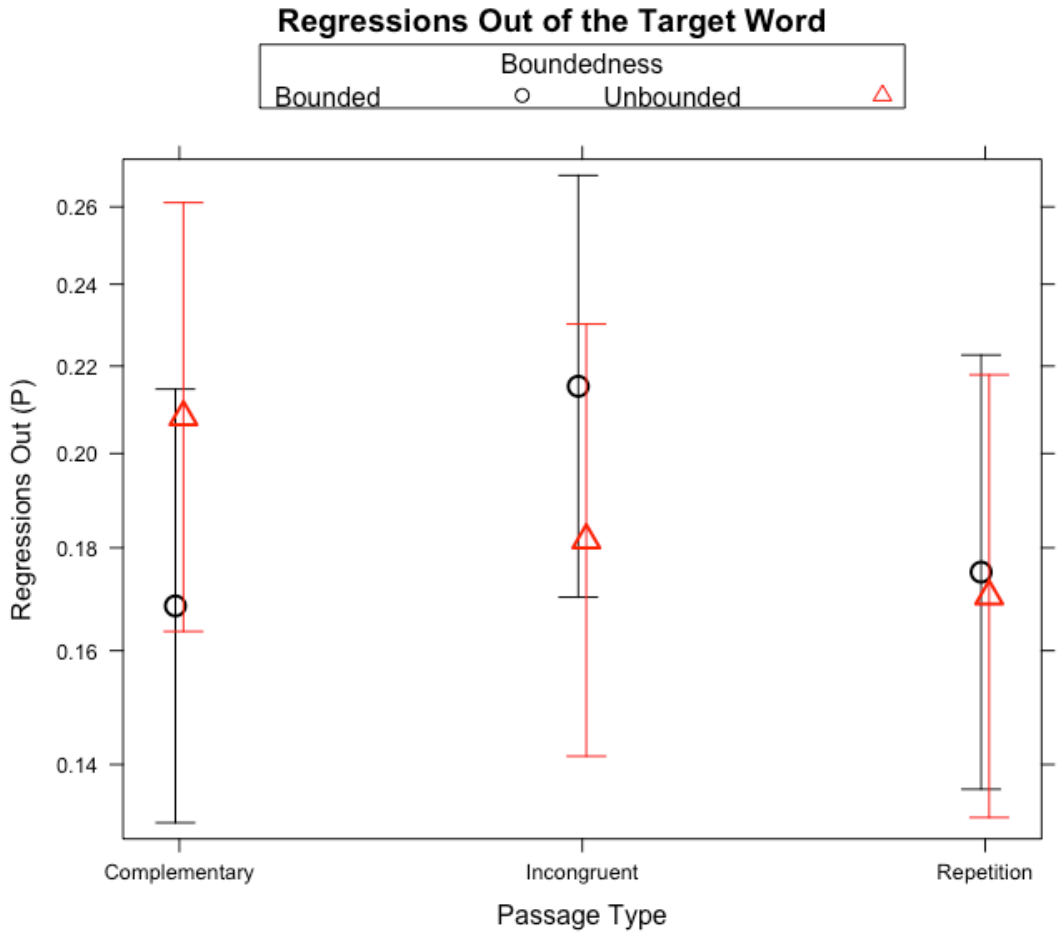

Figure 3.2. Regressions out of the target region for all conditions. Means and standard error bars

The gaze duration and regression results together provide insight into two important aspects of early linguistic processing at the target word. First, readers showed sensitivity to the manipulation of boundedness with negation prior to a saccade to leave the target word. That is, there was an impact of the manipulation on oculomotor behaviour that was quite rapid. Second, the specific influence on eye movement behaviour was differential, contingent on whether the incongruent negated expression was bounded or unbounded. When unbounded, gaze durations were inflated, whereas when bounded, readers were significantly more likely to make an immediate regressive saccade to re-inspect text earlier in the passage. Furthermore, these saccades were made without any increased fixation times. To be clear, not only were there rapid effects for both the bounded and unbounded conditions, the nature of those effects differed qualitatively across conditions. This further demonstrates that readers were rapidly sensitive to this aspect of the experimental manipulation and that they modulated their oculomotor response

contingent on the nature of the manipulation. One possible interpretation of the results is that anomaly detection in the bounded incongruent condition was so rapid (due to the mutual exclusivity of the states conveyed by bounded negation) that readers immediately regressed back in the text in order to check their interpretation of the pair of negated expressions. In contrast, the unbounded negation led to increased gaze durations on the target word, which may reflect processing necessary to integrate two unbounded expressions that are not mutually exclusive (e.g., integration of *not early* and *not late*).

Bounded Analyses

Analyses of Later Measures for Target Region

First, consider the measure of go past reading times for the target word. Note that go-past reading times include both fixations on the target word, and those made on earlier regions prior to making a fixation to the right of the target. For this reason, this measure was considered separately for the bounded and the unbounded passages. For the bounded passages, go-past reading times were longer for the target word region in the incongruent compared to the repetition condition. As no corresponding difference was found in gaze durations for the target, the go-past reading time difference must derive from increased processing time (i.e., increased numbers of, potentially, longer fixations) for previous content in the passage. This notion is supported by the corresponding increased numbers of regressions out of the target region in the incongruent relative to the repetition and complementary conditions. There was no increase in go-past reading times in the complementary condition relative to the repetition condition, suggesting that the disruption observed in gaze duration (reported earlier) was short-lived. There was also a significant effect of total reading time, such that more time was spent fixating the target region in the incongruent and complementary condition compared to the repetition condition.

Post Target Region

In the bounded conditions, there were no effects for first-pass reading time in this region. There were, however, more regressions from this region in the incongruent than the repetition or the complementary conditions. A very similar

pattern of effects was observed for go-past and total reading times for this region, such that longer reading times were found in this region for these measures in the incongruent condition compared to the repetition and complementary conditions. These results suggested that disruption to processing continued during fixations made on regions beyond the target word, but only when an antonym was incongruent with a negated bounded expression that appeared earlier in the text.

Wrap Up Region

There were no effects of first-pass reading time in this region. There was, though, an increased likelihood of a regression out of the wrap-up region, and similarly, longer go-past reading times in the incongruent than in the repetition or complementary conditions. Again, both these effects suggest continued disruption to processing when the antonym was incongruent with a preceding negated bounded expression. Furthermore, disruption continued to the end of the reading of the passage, as the wrap-up region represented the final sentence of each text.

Analyses of Pre-Target Regions

There were no reliable effects in the first sentence context or first negation. For the first antonym region, more regressions were made into this region and more time was spent reading this region in the incongruent than repetition or the complementary conditions. A very similar pattern of effects was found in the second negation region. For the second antonym contextual sentence, readers made more regressions into this region in the incongruent condition compared to the repetition and complementary conditions, but there were no reliable corresponding differences in total reading times. To summarize, the results for the pre-target regions in the bounded passages are overall in line with the predictions made in this Chapter, in that, readers experienced more disruption in the incongruent condition than in either the complementary or the repetition conditions.

To summarize all of these findings, the bounded incongruent condition resulted in significantly more regressions out of the target region, which was the site at which the semantic content of the passage became anomalous. This occurred

without any increase in first-pass fixation times, suggesting that readers rapidly assessed the text as anomalous. As a result, go-past reading times for the target were longer in the bounded incongruent condition than the other conditions. Increased regressions out of the post-target and wrap-up regions, and longer go-past times for these regions for the incongruent condition also suggest disruption durably continued throughout the reading of the rest of the passage. In contrast, in the bounded complementary condition, the only disruption observed occurred on the target region. This was consistent with the prediction made that readers would easily integrate complementary bounded negations, due to the high level of semantic similarity between a bounded negation and its antonym.

Unbounded Analyses

Analyses of Later Measures for Target Region

As before, the unbounded results were considered independently from the bounded results. Go-Past and total reading times on the target were longer for the incongruent and complementary conditions compared to the repetition condition. The unbounded incongruent condition also yielded longer total reading times than in the complementary condition. Once again, these results were comparable to the effects observed in gaze duration for the target word, and show that there was disruption in both the incongruent and the complementary conditions, relative to the repetition condition. To reiterate, these results were consistent with the prediction that both the unbounded complementary incongruent conditions would both cause disruption to processing.

Post Target Region

There were no effects for first-pass reading time for this region. Readers made more regressions out of the post-target region, and had longer Go-Past and total reading times in both the incongruent and complementary conditions relative to the repetition condition. The unbounded incongruent Go-Past reading times and regressions out were significantly increased compared to the unbounded complementary condition also. These results are in line with the predictions made previously and suggest that disruption to reading of complementary and incongruent passages spilled over into the post-target region.

Wrap Up Region

No effects were observed for first-pass reading time, regressions out or total reading time measures. There were more regressions out of this region in the incongruent compared to the complementary and repetition passages, but no increases in reading times were found for this region.

Analyses of Pre-Target Regions

More regressions were made into the first antonym sentence context in the complementary condition compared to both the repetition and incongruent conditions. No effects were found in total reading time for this region. More regressions were made into the first antonym region in the incongruent compared to both the repetition and complementary conditions. No effects of total reading time were found for this region. There were no effects in the second antonym sentence context region, and no regression-in effects were found for the second negation region. There was a significant effect of total reading time, such that more time was spent fixating this region compared to the repetition region.

To summarize, once again, for the unbounded passages it is clearly the case that both the incongruent and the complementary conditions produced disruption to processing relative to the repetition condition. This was evidenced by increased reading times and regression rates in the target and post-target regions for both the unbounded incongruent and complementary conditions. This pattern of results differs from the pattern obtained for the bounded passages (where difficulty arose from the incongruent condition alone). The pattern of effects for the unbounded passages also meets with the predictions made previously, which were motivated by the low semantic similarity shared between unbounded negation and its antonym. Furthermore, the lack of increased reading times in the wrap-up region suggests readers had largely overcome any processing difficulty before reaching the end of the passage.

Table 3.4. Mean reading times and standard deviations for regions 1-8.

Measure	Condition	Region	1st Antonym Context		First Negation		First Antonym		2nd Antonym Context		Second Negation		Target		Post-Target		Wrap Up	
			M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
First Fixation Duration	Bounded - Repetition		-	-	-	-	221	91	-	-	230	76	220	73	-	-	-	-
	Bounded - Incongruent		-	-	-	-	237	104	-	-	234	83	227	78	-	-	-	-
	Bounded - Complementary		-	-	-	-	232	98	-	-	236	85	229	73	-	-	-	-
	Unbounded - Repetition		-	-	-	-	227	97	-	-	236	78	219	65	-	-	-	-
	Unbounded - Incongruent		-	-	-	-	221	89	-	-	228	76	229	78	-	-	-	-
	Unbounded - Complementary		-	-	-	-	236	95	-	-	233	82	228	74	-	-	-	-
Gaze Duration/ First-Pass Fixation Time	Bounded - Repetition		1456	812	285	141	275	168	830	577	249	99	242	105	632	417	1588	811
	Bounded - Incongruent		1453	785	274	132	291	180	801	551	255	111	253	113	623	424	1526	746
	Bounded - Complementary		1533	849	-	-	278	152	818	551	255	107	260	119	638	453	1572	772
	Unbounded - Repetition		1282	798	291	169	279	178	791	608	255	103	239	97	538	328	1554	777
	Unbounded - Incongruent		1266	751	278	134	271	164	782	583	247	109	254	116	562	378	1555	746
	Unbounded - Complementary		1340	795	-	-	294	179	801	628	255	117	249	104	543	337	1580	816
Go Past Reading Time	Bounded - Repetition		-	-	-	-	-	-	-	-	-	-	313	214	809	586	1839	1081
	Bounded - Incongruent		-	-	-	-	-	-	-	-	-	-	362	299	1035	805	1936	1176
	Bounded - Complementary		-	-	-	-	-	-	-	-	-	-	334	241	867	671	1833	1127
	Unbounded - Repetition		-	-	-	-	-	-	-	-	-	-	295	161	717	525	1834	1068
	Unbounded - Incongruent		-	-	-	-	-	-	-	-	-	-	331	233	999	786	1891	1100
	Unbounded - Complementary		-	-	-	-	-	-	-	-	-	-	330	218	809	646	1804	949
Total Reading Time	Bounded - Repetition		1743	1065	380	226	350	245	978	704	310	176	289	187	733	483	1672	815
	Bounded - Incongruent		1749	1017	394	257	391	298	999	703	358	219	361	259	826	531	1657	740
	Bounded - Complementary		1783	984	-	-	354	233	975	696	325	172	314	197	763	509	1657	786
	Unbounded - Repetition		1519	948	392	254	348	245	918	691	315	194	278	154	622	392	1661	771
	Unbounded - Incongruent		1563	1013	385	239	375	277	953	725	353	218	347	224	741	460	1675	776
	Unbounded - Complementary		1523	941	-	-	361	239	935	714	334	193	317	202	672	404	1668	804

Table 3.5. Mean regression rates and standard deviations for regions 1-8.

Measure	Condition	Region	1st Antonym Context		First Negation		First Antonym		2nd Antonym Context		Second Negation		Target		Post-Target		Wrap Up	
			M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Regressions Out	Bounded - Repetition		-	-	-	-	-	-	-	-	-	-	0.20	0.40	0.41	0.42	0.22	0.41
	Bounded - Incongruent		-	-	-	-	-	-	-	-	-	-	0.25	0.43	0.43	0.43	0.27	0.44
	Bounded - Complementary		-	-	-	-	-	-	-	-	-	-	0.20	0.40	0.42	0.41	0.21	0.41
	Unbounded - Repetition		-	-	-	-	-	-	-	-	-	-	0.20	0.40	0.23	0.42	0.22	0.42
	Unbounded - Incongruent		-	-	-	-	-	-	-	-	-	-	0.21	0.41	0.49	0.49	0.27	0.44
	Unbounded - Complementary		-	-	-	-	-	-	-	-	-	-	0.23	0.42	0.28	0.45	0.21	0.41
Regressions In	Bounded - Repetition		0.48	0.50	0.26	0.43	0.03	0.16	0.26	0.44	0.29	0.45	-	-	-	-	-	-
	Bounded - Incongruent		0.51	0.50	0.27	0.46	0.06	0.24	0.32	0.47	0.38	0.48	-	-	-	-	-	-
	Bounded - Complementary		0.47	0.50	-	-	0.03	0.18	0.26	0.44	0.30	0.46	-	-	-	-	-	-
	Unbounded - Repetition		0.50	0.50	0.27	0.45	0.03	0.18	0.25	0.43	0.30	0.46	-	-	-	-	-	-
	Unbounded - Incongruent		0.52	0.50	0.31	0.46	0.06	0.23	0.34	0.48	0.36	0.48	-	-	-	-	-	-
	Unbounded - Complementary		0.43	0.50	-	-	0.03	0.17	0.27	0.45	0.34	0.47	-	-	-	-	-	-

Table 3.6. Fixed effect estimates from the linear mixed effect models for gaze duration/first-pass fixation time, regressions out, go-past and total reading time measures for target, post-target and wrap up regions.

Measure	Bounded Gaze Duration/First Pass Reading Time		Bounded Regressions Out		Bounded Go-Past Reading Time		Bounded Total Reading Time		Unbounded Gaze Duration/ First Pass Reading Time		Unbounded Regressions Out		Unbounded Go-Past Reading Time		Unbounded Total Reading Time	
	b	*t*	*b*	*z*	*b*	*t*	*b*	*t*	*b*	*t*	*b*	*z*	*b*	*t*	*b*	*t*
Target Region																
Intercept	-	-	-	-	311.34	19.99	285.84	22.98*	-	-	-	-	289.29	23.86*	274.58	25.54*
Incongruent	-	-	-	-	48.22	3.31*	72.25	6.70*	-	-	-	-	39.55	3.55*	68.79	5.98*
Complementary	-	-	-	-	21.76	1.59	24.06	2.22*	-	-	-	-	38.52	3.42*	38.51	3.41*
Contrast	-	-	-	-	-0.04	-1.6	-48.19	-4.48	-	-	-	-	-1.03	-0.09	-30.28	-2.69
Post Target Region																
Intercept	630.35	14.81*	1.49	10.31	807.74	15.04	731.31	13.7	533.76	15.62*	1.34	9.50*	712.33	17.36*	617.33	15.42
Incongruent	-9.28	0.55	0.80	6.86	225.08	7.28*	91.83	5.00*	27.42	1.95	0.91	7.15*	286.99	6.94*	123.67	5.37*
Complementary	6.01	0.32	0.14	1.15	56.2	1.94	30.3	1.65	7.19	0.53	0.31	2.62*	95.54	2.93*	51.8	2.92*
Contrast	15.29	0.89	0.66	5.76*	-168.87	-5.55*	61.52	-3.34*	20.24	1.35	0.59	5.04*	-191.44	-3.90*	-71.87	-3.13
Wrap-Up Region																
Intercept	1589.08	20.23*	1.47	10.35*	1840.17	20.17	1670.87	4076.00	1552.29	19.89*	1.43	9.97*	1831.59	20.78	1659.8	48.15
Incongruent	-63.93	1.85	0.3	2.55*	94.89	2.01*	-13.94	-0.35	0.34	0.01	0.26	2.20*	58.03	0.96	14.98	0.41
Complementary	-17.18	0.54	0.04	0.34	-4.99	-0.11	-14.13	-0.37	27.57	0.74	0.09	0.72	-28.09	-0.52	7.58	0.21
Contrast	46.74	1.53	0.35	2.89*	-99.88	-2.06*	-0.37	-0.01	27.91	0.78	0.35	2.91	-86.12	-1.47	-7.39	-0.20

*Note, * t>1.96. Incongruent refers to comparison between repetition and incongruent passages. Complementary refers to comparison between repetition and complementary passages. Contrast refers to comparison of complementary and incongruent conditions.*

Table 3.7. Fixed effect estimates from the linear mixed-effects models for total reading time and regressions in for pre-target regions.

Measure	Bounded Regressions In		Bounded Total Reading Time		Unbounded Regressions In		Unbounded Total Reading Time	
	Estimate	*z* value	Estimate	*z* value	Estimate	*z* value	Estimate	*z* value
First Antonym Sentence Context								
Repetition (Intercept)	-0.11	0.47	1743.54	87.49*	-0.02	0.11	1515.82	13.63
Incongruent	0.18	1.66	5.62	1.81	0.11	0.92	47.17	1.41
Complementary	-0.02	-0.18	39.25	0.80	-0.33	2.17*	29.89	0.92
Contrast	-0.20	1.77	33.63	0.68	-0.44	3.60	-17.28	0.50
First Antonym								
Repetition (Intercept)	-4.34	11.81*	334.44	19.47*	-1.21	9.40*	332.05	18.87
Incongruent	1.01	3.24*	36.51	2.53*	0.50	4.46*	25.83	1.60
Complementary	0.31	0.89	9.34	0.70	0.13	1.12	14.38	0.95
Contrast	0.71	2.51*	-27.10	7.77*	-0.37	3.36*	-12.20	0.84
Second Antonym Sentence Context								
Repetition (Intercept)	-1.18	8.22*	977.71	11.57*	-0.96	7.04	897.05	10.35
Incongruent	0.34	2.60*	14.83	0.64	0.32	2.44	31.77	1.40
Complementary	-0.02	-0.14	-3.41	0.15	0.20	1.53	17.08	0.74
Contrast	-0.36	2.80*	-18.25	0.79	-0.12	0.91	-14.69	0.48
Second Negation								
Repetition (Intercept)	-1.01	7.42*	303.59	21.67*	-0.96	7.04	298.98	18.59
Incongruent	0.47	3.68*	51.53	3.97*	0.32	2.44	38.11	3.14*
Complementary	0.10	0.74	19.05	1.63	0.20	1.53	20.18	1.64
Contrast	-0.37	2.94*	32.48	2.46*	-0.12	0.91	-17.94	1.50

*Note. * t>1.96. Incongruent refers to comparison between repetition and incongruent passages. Complementary refers to comparison between repetition and complementary passages. Contrast refers to comparison of complementary and incongruent conditions.*

Experiment 2: Discussion

Experiment 2 used measures of eye movements during reading to examine the influence of boundedness on the on-line processing of negated entities in passages. Evidence of effects on eye movement measures were interpreted as suggest that on-line linguistic processing is affected by the boundedness of a negated entity. For bounded incongruent passages, upon fixating a negated antonym participants

immediately made a regression to re-read earlier portions of the passage. Readers also made more regressions from later regions and spent longer re-reading earlier regions of the passage in the bounded incongruent condition relative to complementary and repetition conditions. Bounded complementary passages only produced disruption in gaze duration and total reading time on the negated antonym.

In contrast to this pattern, in the unbounded conditions, readers experienced disruption in both the complementary and the incongruent conditions relative to the repetition condition. Increased gaze durations were observed on the negated antonym (target word), but unlike the bounded stimuli, there was no increase in the likelihood of regressions out of this region. There was also evidence of disruption to later measures (go-past, regressions out and total reading time) in the post-target region. Again, across these measures and regions, disruption was observed for both the complementary and incongruent conditions relative to the repetition condition.

The eye movement data provide evidence to support a number of important conclusions. First, it appears that within a readers' discourse representation, semantic ontological information is encoded in some form. As this process appears to occur on-line during incremental interpretation of text, there was a differential sensitivity (in terms of oculomotor response) associated with the comprehension of boundedness in relation to negated antonym interpretation. Upon fixating an incongruent bounded negated antonym, readers immediately regressed to re-read earlier portions of the passage, whereas readers' initial gaze on a comparable unbounded complementary or incongruent antonym increased in duration (presumably reflecting processing difficulty) without any increased likelihood of regressive eye movements.

Two subsequent conclusions follow from these results. First, there was a quite immediate differential sensitivity to bounded and unbounded negated antonyms. Readers showed a rapid appreciation of the difference in semantic status of a negated antonym, contingent on whether it was bounded or unbounded (and this occurred during the period of the initial fixations on the antonym). Secondly, on the basis of the development of such differential understanding, readers undertook qualitatively different oculomotor actions as a response. The interpretation of these results here is that language processing is sensitive to subtle differences in the status of linguistic expressions with respect to boundedness.

The eye movement results were informative about the qualitatively different decisions readers made upon reaching an incongruent negation, contingent on whether the negated entity was bounded or unbounded. In the target word analyses, it was possible to directly evaluate eye movement behaviour across the different boundedness conditions because the regions of text being compared were carefully matched. Differential eye movement patterns were found in the reading of bounded and unbounded incongruent passages. A critical question concerns why the patterns of eye movements at the negated antonym were different across these conditions. First, recall that it was predicted that disruption to processing would be greatest in the bounded incongruent condition due to the mutual exclusivity of the two states described by the negated antonyms. As such, increased regressions immediately out of this region were observed for this condition, with no increase in first pass fixation times. To be clear, it appears that in this condition, upon detecting a severe incongruity (in fact, a contradiction) upon fixating the target, readers rapidly initiated an oculomotor action. This has often been characterised as a method, on the part of the reader, for checking whether they initially misinterpreted some aspect of the preceding text (Frazier and Rayner, 1982; Rayner et al., 2004). In line with the theoretical position of this thesis, it is concluded here that effect was a very rapid response to detection of the incongruity occurred as a direct result of the contradictory nature of the bounded negated antonyms.

It has previously been shown that when text is anomalous (e.g., when an object represents a verb argument violation – *using a pump to inflate carrots*) disruption to processing occurs more immediately and for a longer duration than when text describes events that are simply unlikely (e.g., *using an axe to chop carrots*) (see Braze et al., 2002; Murray & Rowan, 1998; Rayner et al., 2004; Traxler et al., 2000; Warren & McConnell, 2007). Similarly, on this basis, it seems reasonable to suggest that detection of two statements that are contradictory (e.g. integrating a representation of *not dead* with a representation *not alive*) would result in maximal and immediate disruption, such as, an immediate regression to very rapidly check the validity of the initial interpretation of preceding text.

Next, consider the unbounded complementary (*early*, *not late*), unbounded incongruent (*not early*, *not late*) and bounded complementary (*dead*, *not alive*), conditions. For all three of these conditions it is possible to attain a representation

that is consistent with both antonyms, though computation of that representation requires inferential processing. To be clear, for these conditions there was no contradiction with respect to the negated antonyms, but rather a degree of inferential processing (presumably reflected in increased first pass fixation durations). As such, there was no immediate need to regress to check the initial interpretation of the earlier text. Within this experiment, the decision to move the eye forwards or backwards in the text was, in part, driven by whether there was a text-level contradiction present.

For additional analyses in which eye movement behaviour was compared for regions other than the target, bounded and unbounded conditions were considered separately, due to unavoidable content differences across the passages. In the bounded conditions, bounded incongruent passages produced disruption to processing that was extended (increased regressions and re-reading times associated with the post target regions), relative to the repetition and complementary passages. These differences appear to be in line with the explanation developed above, whereby, the bounded incongruent negated antonyms resulted in a contradiction that could not be logically integrated. In contrast, all other bounded conditions were perfectly consistent. The incongruent condition led to rapid regressions and disruption to processing that continued downstream in the passage. This was not the case for the bounded complementary and repetition conditions. It is in this manner that the data from Experiment 2 appeared to show that readers demonstrated sensitivity to the categorical nature of bounded concepts on-line during natural reading. Again, this pattern of effects is consistent with the predictions that were generated from the offline similarity ratings from Experiment 1c.

Now consider the analyses of the data from the unbounded conditions. Here disruption to reading of the passage was found in both the incongruent and complementary passages, relative to the repetition passages. This disruption took the form of increased go-past time for the post-target region and increased regressions from the post target and wrap up regions. Again, this pattern of effects seems reasonable based on the similarity ratings obtained in Experiment 1c. It is suggested here that these effects are based on the degree to which inferential processing is necessary to reconcile the two negated antonyms in the unbounded incongruent (*not early*, *not late*) and complementary (*early*, *not late*) conditions relative to the

repetition condition. Recall, in Experiment 1c, the antonyms in the unbounded incongruent and complementary passages were judged as being less similar to each other than were the antonyms in the repetition condition. These judgment differences presumably reflect the fact that in the unbounded incongruent condition (*not early*, *not late*), while it is possible to reconcile the two negated antonyms (i.e., *on time*), an inferred state that is not explicitly denoted within the text must be attained. Similarly, readers must infer that the complementary negation (*not early*) could refer to a previously denoted state (*late*). This inference is required because the negation, in isolation, could refer to two possible states (i.e., *on time*, or *early*). Such inferential processing is not needed when the antonym is explicitly repeated. It is suggested that it was this processing that led to the increased disruption to processing downstream from the negated antonyms in the unbounded incongruent and unbounded complementary conditions.

The data presented in this thesis so far provide evidence to suggest that bounded negation is interpreted as synonymous with its antonym, while unbounded negation can be interpreted as multiple possible states, or is left underspecified. Research on processing of grammatical aspect (the temporal duration of events) suggests readers underspecify representations of unbounded events (Madden & Zwaan, 2003; Pickering, McElree, Frisson, Chen & Traxler, 2006). For instance, the imperfective verb *hopping* has no logical end-point and captures more possible states than the perfective *hopped*. As the imperfective verb is considered unbounded, readers have been suggested to underspecify these types of representation until necessary. So for the sentence *the insect was hopping*, readers do not represent which point within the *hop* the *insect* is at (beginning, a mid-point, or the end), unless this is disambiguated. This is not required for unambiguous, perfective terms (*the insect had hopped*). Further research is required to differentiate between these possibilities in relation to processing of unbounded negation during natural reading.

More generally, the current findings regarding boundedness have important implications for theoretical accounts of how readers process negation. Two-step theory predicts a universal delay in the processing of negation (Kaup, 2001; Kaup, 2011; Kaup & Zwaan, 2003). This delay would be caused by the necessity to always first instantiate the affirmative representation, before representing the negated element. In Experiment 2, however, immediate delays were found in all non-

repetition conditions (i.e. regressions out or first pass reading time), suggesting there was an immediate recognition of any incongruity or ambiguity within the negated items. These results cannot currently be integrated with a two-step processing account of negation, which does not allow for the processing of negation without some form of delay.

Alternatively, the data from Experiment 2 provide a degree of support for a Dynamic Pragmatic theory of negation. Dynamic Pragmatic accounts of negation stipulate that the number of alternative states generated by a negation has a direct impact on how that negation is processed (Beltran et al., 2008; Giora, 2006; Nieuwland & Kuperberg, 2008; Orenes, Moxey, Scheepers & Santamaria, 2015; Tian et al.; 2010; 2016;). Within this account, bounded negation only has one alternative (*not dead* must be *alive*); hence it is processed quickly and definitively. This could be reflected in the rapid incongruity detection (increased regressions out of the target) and durable disruption (increased reading times and regression rates on the post-target and wrap-up regions) that occurs from when the negated target antonym is first encountered in the bounded incongruent condition. In this condition, it was immediately apparent that the two states are contradictory and mutually exclusive. Unbounded negation, in contrast, can be interpreted as multiple states, and thus, it has been said to be instantiated into the discourse representation more slowly. Hence, in these conditions surmountable disruption to processing was found, as readers disambiguate the multiple possibilities presented by the incongruent and complementary negations.

Dynamic Pragmatic accounts have been shown to offer a broad explanation of the results of Experiment 2. It is also the case that they are not currently sufficiently well specified to explain modulatory influence of boundedness on processing of negation. On the basis of these eye movement results, it is possible to extend such accounts by specifying that when negated expressions are categorical, readers can rapidly interpret the mutual exclusivity of states, allowing for rapid integration of such information into the discourse representation. This is advantageous when these items are consistent as reading can proceed optimally. When negated antonyms are inconsistent, however, readers immediately recognize the incompatibility of incongruent states and struggle to overcome the logical contradiction. Such difficulty is unsurprising, as there is no possible integrated state to represent. In this way, it can

be stipulated that bounded expressions provide an immediate linguistic constraint on the nature of sematic processing, acting to limit the set of potential interpretations a reader can achieve. In contrast, for unbounded negation, it appears that disruption to processing manifested differently (increased fixation durations rather than immediate regressions) and was less catastrophic, in that, ultimately, resolution of the negated antonyms was possible. To be clear, the disruption observed for unbounded negated entities reflected processing associated with ambiguity resolution in the form of the computation of a shared state from a larger set of potential states. Thus, at a more general level, the results of Experiment 2 can be taken to suggest that disruption to processing occurs when readers process bounded or unbounded negated antonyms. Furthermore, that disruption reflects processing that is qualitatively different in the two situations (with each having a different pattern of oculomotor behaviour accordingly).

As outlined within the Literature Review, there are also several other current models of negation that should be considered alongside Dynamic Pragmatic theory. As previously noted, Anderson et al. (2010, 2011) conceptualized sentence processing within a three-dimensional state space upon which states are indexed. The processing of language causes propositions to create trajectories of activation that are indexed to the matching location in space. In this account, a negation causes multiple states to be activated, these two compete and activation spreads between themselves and to neighbours in nearby semantic space (Fauconnier & Turner, 2002). In the case of a bounded negation, it could be argued that one dominant state space can be activated, as the dimension is categorical. In the case of unbounded negation, however, many possible states are activated as the denial of one state still allows many possible states upon the dimension to be activated. The ambiguity within unbounded negations causes multiple states to compete for activation and this is taken to explain the processing delay in comprehending unbounded negative sentences. While this theory can accommodate the processing of negation in terms of speed of representation, the theory does not consider accommodation of representations where the congruency of two negated items are dependent on the boundedness of those concepts.

Khemlani, Orenes and Johnson-Laird's (2012) theory of negation

representation also utilized a mental model design. During negation, they argued mental models of any possible state are constructed and updated during language comprehension. As each possibility is simulated, the more possibilities a negation could refer to, the more mental models that need to be constructed. This context-led approach also posits that the construction of needless models is blocked, therefore, negated core suppositions with only two predicates (e.g. *alive-dead*) only cause the construction of one mental model. A negative core supposition with an ambiguous amount of predicates (e.g. *tall/short*), however, leads to the creation of many models, which compete for activation, hence a delay in negation processing of negated entities with multiple possible predicates. Furthermore, the increased number of alternatives in the unbounded conditions could also be used to explain the processing delay in attempting to integrate complementary and incongruent negations. As previously noted, however, further research is required to see whether readers do represent all possible alternatives. An alternative hypothesis would suggest readers choose to underspecify unbounded negation, with further experimentation required to differentiate which two of these possibilities occur during unbounded negation interpretation.

Importantly, there was no interaction of markedness in the results of Experiment 2 for either the bounded or unbounded passages. In terms of negation processing, Fraenkel and Schul (2008) suggested negating unmarked members of unbounded antonym pairs pushes a reader's semantic representation closer to the antonym. For example, negating the unmarked member was synonymous with its antonym (e.g. *not good = bad)*, unlike negating the negative, marked member (*not bad ≠good*). They argued this is because the marked members derive their meaning from being contrast items to the unmarked member, thus negating what is already a contrast item weakens the negative effect. If this were the case, an interaction should have been observed in the unbounded complementary case, as negating the marked antonym (*bad – not good)* would have caused less disruption to reading than when negating the unmarked antonym (*good – not bad*). As there was no effect of markedness, controlled for in the counterbalancing of antonym order, it can only be surmised that while markedness affects offline assessment of negated propositions, readers show no sensitivity to this variable during online language processing.

Previous investigations have found effects of boundedness on negation interpretation using offline measures (Du et al., 2014; Mayo et al., 2004; Paradis & Willners, 2006). Furthermore, visual world studies (Anderson et al., 2010; 2011; Orenes et al., 2014) have reliably concluded that the number of alternatives a negated entity effects how it is interpreted. In contrast, Experiment 2 provides novel evidence that boundedness has an early influence on the online processing of negation during reading. The data from Experiment 2 appear to indicate that at least some aspects of negation are computed quickly, and the use of eye movement methodology affords the potential for subtle qualitative differences in processing to be identified. For this reason, it should be considered that using eye movement recordings to investigate processing of negation in reading is a valuable approach for future research.

An issue of future concern is whether the processing of unbounded negation is equivalent throughout all unbounded concepts. In Experiment 2, a clear categorization was made between bounded and unbounded concepts. In this categorization, unbounded concepts referred to those that denote at least two other states when negated. There is, however, a large amount of semantic variability within unbounded concepts. It is possible for an unbounded negation to refer to *only* two other states, for instance, *not early* refers to either *late* or *on time. Not cold,* however, can refer to many possible states along a scale ranging from *hot* to an intermediate position within the entity's scalar ontology. Further research will need to determine more precisely the relationship between number of states and access to negated content. It is perfectly reasonable, within a pragmatic account of negation, to predict that the case of *not late* is less ambiguous than the case of *not hot* as the former's ontology has fewer states, suggesting it may be instantiated more quickly. Understanding the relationship between the variability of an unbounded concept's ontology (3 vs. >3 states) may also inform the manner in which negated concepts are instantiated.

A further point of interest is how context might affect the specificity of instantiating an inferred state. A key difference between the two previously mentioned types of unbounded concepts is that in three state concepts, no context of comparative set is required in order to compute the negation, whereas it is required in the scalar case (Breheny, Katsos & Williams, 2006; Kennedy, 1999). The third state

available in the concept of *late* and *early* is *on time*, a definitive state that does not require context in order to be correctly understood. The inferred state from the negation does not change in meaning whether referring to a *train, employee* or *piece of coursework*. On the other hand, terms like *hot, cold, wide* and *narrow* require context in order to be successfully comprehended. For instance, using the term *hot* is clearly going to have very different intentions when talking about *lava* rather than *coffee.* As the scale is unbounded (and has no clear endpoints), *hot* is a term that further denotes one end of the scale based on context and its referent. Language processing systems, however, are able to deal with these constantly changing demands effortlessly. Further research is required in order to evidence how the language processing system is capable of constantly adapting the scale of unbounded concepts in order to fit the item being denoted. [1]

In sum, Experiment 2 provided novel evidence that boundedness affects the semantic interpretation of negation during online sentence comprehension. The findings of Experiment 2 indicate that readers are highly sensitive to whether negation implied a clear opposite or is underspecified and includes this information as part of their unfolding representation of the discourse. Furthermore, boundedness provides another variable that can be accommodated within Dynamic Pragmatic theories in order to correctly account for negation processing. This is contrary to predictions provided by two-step theories of negation processing (Kaup & Zwaan, 2003; Kaup, Ludtke & Zwaan, 2006; Kaup, Yaxley, Madden & Zwaan, 2007), which stipulated an obligatory first stage to processing, reflected by a global cost of negation processing relative to their affirmative equivalent.

[1] In order to see if there was any effect of this distinction in the unbounded dataset, the LME models from Experiment 2 were rerun with an interaction term that distinguished between these two types of unbounded concept. No effect or interaction was found in any of the models to suggest that concepts with only three possible states were disambiguated more quickly than scalar concepts with many possible states. Further investigation with a formalized manipulation of this configure distinction, however, is still required. Within this investigation, no pre-tests were run to test whether concepts were three or more than three states, and the concepts were not balanced, with 24 more than 3 states concepts, and 12 three states concepts. As such, further investigation is required to empirically investigate this variable.

Chapter 4

An Eye Movement Investigation of the Effects of Connectives on the Processing of Boundedness and Negation

In Experiment 2, it was shown that readers are sensitive to the linguistic operator of boundedness and it is processed on-line during language comprehension. In Chapter 4, the differential processing of bounded and unbounded text during on-line language processing is explored further, through the use of connectives.

Connectives are discourse markers, usually placed in between two units of text (clauses/sentences) in order to denote the relation between those units of text. For example, *because* indicates that the second clause is as a direct consequence of the first, whereas adversative connectives such as *but* and *however* indicate that the first clause is suppositional to the content of the second clause. It has been well reported in the psycholinguistic literature that the felicitous use of connectives allows for faster processing of text (Cozijn, 2000; Haberlandt, 1982; Millis & Just, 1994; Murray, 1995; Xu, Chen, Panther & Wu, 2017). This literature will be discussed in this chapter. Furthermore, the notion that connectives are processed as a part of incremental interpretation of text is also discussed. Findings suggest connectives are processed as a part of incremental interpretation of text (Traxler, Sanford, Aked & Moxey, 1997; Traxler, Bybee & Pickering, 1997), rather than affecting processing on a propositional level (Millis & Just, 1994).

In Experiment 3, connectives were placed in between the two antonym usages in the passages from Experiments 1c and 2. These are used to indicate that there will be agreement or disagreement between the two characters in the passages. Due to the processing speed benefit in bounded items, the facilitatory effect often seen with connective use should exhibit itself earlier in the case of bounded items, compared to unbounded items. In the next section, the connective literature is reviewed, as well as its use as a tool in investigating incremental text interpretation.

Introduction

When correctly comprehending text, readers must not simply interpret the meaning of individual sentences. In order to correctly understand the wider narrative, readers must also correctly integrate the relationship between different units of text. One way in which this relationship is explicitly denoted, is through the use of connectives. In the psycholinguistic literature, connectives refer to function words used to coherently relate/integrate adjacent clauses together (Hobbs, 1979).

Early research into connectives compared the processing of connectives in different age groups to understand the development of perceptual order (Piaget, 1948; Walker-Katz & Brent, 1968) and in different languages (such as comparing German and English in Werner & Kaplan, 1963; and French in Caron, Micko & Thuring, 1988). More recent research has investigated the specific effects of connectives on sentence comprehension and incremental interpretation. The most commonly used connectives found in the literature include *and, because* and *but*. The relationships these connectives denote differ. For instance, *and* is called a temporal connective meaning the two clauses it is placed between occurred alongside or together, for example *melt the butter **and** the sugar together* (Vygotsky, 1962). On the other hand, *because* is a causal connective meaning it is used to denote that the first clause is a direct result of the second (Haberlandt, 1982). For example, *I was very scared **because** she shouted at me.* The final example *but* is an adversative connective, which is used to deny any causal relationship and, furthermore, asserts that the first clause before the connective is suppositional to the content of the second clause (Townsend & Bever, 1978). For example, *my legs ached **but** I kept running.* Recently, research into connectives has looked at the different impact connectives have on readers' discourse representation formation during the reading of multiple clauses, as well as the time course within which this occurs.

Here, research on the integration of connected clauses during sentence comprehension is reviewed. Connective theory is then applied to the findings of Experiment 2 in order to generate theoretically motivated hypotheses about the reading of the boundedness passages when connectives are placed in between the two antonym usages. Experiment 3 investigates how readers comprehend complementary and incongruent negations, when such a relationship has already been denoted by a connective. As such, it provides insight into how understanding of

categorical and scalar concepts affect how readers use connectives to constrain their expectations of upcoming text. The findings, therefore, are relevant to both the growing literature on connective comprehension, as well as increasing our understanding of how boundedness is processed during natural reading.

Propositionalist Accounts

Early cognitive research into the processing of clausal relatedness found faster reading of causally related propositions, compared to unrelated propositions (Haberlandt & Bingham, 1982; Haberlandt, 1982), as well as better recall of related propositions compared to unrelated (Bradshaw & Anderson, 1982). For instance, sentence 1 was read faster than sentence 2, as the causal relatedness between the two clauses allows the reader to easily establish the relationship between the two events, in this case what happens when someone is assaulted. Despite the fact that in typical communication consecutive sentences tend to refer to the same referent (Givon, 1992), sentence 1 is still more coherent due to its more apparent causal relation.

1: *Brian punched George. George called the Doctor.*

2: *Brian punched George. George liked the Doctor.*

The facilitatory effects of causal relations have even been found when no explicit association is placed between clauses, but just prior instruction to readers that two propositions are related.

Anderson and Reder (1979) claimed, in their Elaboration Model of information retention, that material is stored in a propositional network. Propositions with more elaborations create more connections within the network, subsequently leading to better recall. Within this framework, connectives provide readers with explicit instruction to generate more specific elaborations about text. Van Silfhout, Evers-Vermeul, Mak and Sanders (2014) found evidence that school children's comprehension is significantly improved through the use of connectives. The use of more connectives, means the text is providing more "processing instructions". Specifically, the connective provides explicit denotation of the relationship between

units of text, providing readers with information of how to comprehend the relationship. As such, this allowed students to use more efficient comprehension strategies, as they are processing the text without having to make an inference of what the potential relationship could be.

A propositional elaboration account, however, fails to explain effects where propositions connected by an adversative connective actually led to an increase in inferential errors (Caron, Micko & Thuring, 1988). Bransford and colleagues (Bransford, Barclay & Franks, 1972; Bransford & McCarrell, 1974) began a movement towards holistic situational models where all semantic information is constructed in a discourse representation, ultimately moving towards mental model theories discussed in the previous section (Fauconnier, 1985, 1994, 1997). Within these accounts, as readers interpret text, it is structured within an iconic space according to a mental set of representations, which includes all elements and relationships between other sets. Furthermore, a holistic discourse representation allows for interaction between different elements. This is particularly important in the study of connectives, where separate elements are being explicitly related to each other. Instead of maintaining separate propositional representations, a discourse representation allows interaction between multiple elements.

Millis and Just's (1994) Cognitive Integration Model (CIM) of connected clause processing was a propositional theory, in which it was argued that text interpretation only occurs once a reader has reached the end of a proposition. Within this account, it was argued that connectives are utilized when the communicator needs the reader to explicitly integrate the two clauses into a unified representation. Furthermore, this integration is not necessarily present in clauses presented without an intervening connective. In terms of the time course of connective processing, the CIM posited that after reading the first clause, it is instantiated into a discourse representation and, subsequently, the presence of the connective causes the reader to place this representation within an auxiliary memory store. At this point, the semantic information present within the first proposition is 'suppressed'. This means the first proposition has no effect on processing of the second proposition while it is being read. Finally, once the second clause has been instantiated, the CIM model features a reactivation hypothesis, which stipulates that the first representation is reactivated

and integrated with the second clause. This hypothesis stated that once readers reach the end of the second clause, the suppressed first clause is reactivated, allowing for semantic integration of the two clauses

The CIM account was motivated by Haberlandt's (1982) findings that readers were faster to read connective sentences than sentences without connectives. Using self paced reading measures; Haberlandt observed that the increased reading speed was found during the reading of the second clause. Millis and Just (1994) theorized this was due to suppression of the first clause allowing uninhibited interpretation of the second. Haberlandt's data also reflected longer pauses at the ends of sentences/clauses, as would be predicted within a reactivation hypothesis, where integration between multiple propositions would have occurred at this point. There has also been evidence to show causally connective clauses are read quicker until wrap-up where reading times increase (Cozijn, 2000; Cozijn, Noordman & Vonk, 2011), providing further support for the reactivation hypothesis.

To test their predictions based on CIM, Millis and Just carried out a series of experiments using lexical decision tasks, embedded within a self-paced reading task. They manipulated when the lexical decision had to be made. During the reading of the passage, readers had a word probe displayed either before or during the reading of the second clause (see asterisks in sentence 3). They also manipulated whether the lexical decision probe was related to the subject of either the second or first clause. An example can be seen in 3, where the first word in asterisks is when the early probe would have been displayed, and the second is when the late probe would have been displayed. The probe word in this example would have been *toasted* which relates to the first clause more than the second.

3: *The elderly parents toasted their only daughter at the party (because) *Jill* had finally passed the exams at the prestigious *university*.*

Millis and Just (1994) found shorter lexical decision times to probes that were related to the first clause where they were presented at the end of the second clause, rather than midway through the second clause. The authors argued that this suggests that activation of the semantic content of the first clause is suppressed at the time of the first probe. This allowed for the representation of the second clause, without

interference from the first. By the point at which the second probe was presented, it was argued that the reader had reactivated the first clause, and therefore, processing of that probe was facilitated relative to the point in time when the first probe was presented. A discourse model under CIM depicted connectives as one of many linguistic cues (syntactic, lexical, world knowledge etc.) that affected activation at a propositional level of language comprehension.

Millis and Just (1994) also found evidence of clausal and sentence wrap-up times, which are defined as longer reading times on the final word of a sentence/clause, as was seen in Haberlandt's (1982) study. To be clear, in their paradigm, Millis and Just presented the text to the participants one word at a time, with longer reading times observed on the final word of the second clause. Sentence wrap-up, the phenomenon of readers spending longer reading the final words of sentence or clauses, has been characterized as readers updating their discourse model to integrate all relevant information (Just & Carpenter, 1980). This wrap-up effect has been consistently found within the reading literature, in experiments using self-paced reading (shown by longer reading at the presentation of the final word of a sentence, Mitchell & Green, 1978) and eye movement methodology (longer fixations on the final word of words/clauses - Rayner, Sereno, Morris, Schmauder & Clifton, 1989; Rayner, Kambe & Duffy, 2000). Hill and Murray (2000) suggested the hypothesis that sentence wrap-up is due to hesitation when readers reach punctuation signaling the end of a sentence/clause. During this hesitation period, readers are said to fully integrate the text unit into their discourse representation. Hirotani, Frazier and Rayner (2006) offered an alternative hypothesis that increased sentence wrap-up times are actually due to mimicry of prosodic cues presented in spoken language. In spoken language interlocutors pause at the end of segments of words, to regulate airflow. Hirotani et al. argued the wrap-up effect might be due to this artifact from spoken language, rather than time being taken to fully integrate text into a discourse representation.

Warren, White and Reichle (2009) investigated whether the complexity of a clause affects wrap-up reading times by manipulating the complexity of a sentence following a period, comma or no punctuation (see sentence 4a (simple) and b (complex)).

4a. Joe and Bob phoned (./,/_) Before leaving Bob needed directions

4b. It was Joe who Bob phoned (./,/_) before leaving Bob (./,/_) Bob needed directions

They claimed the dual manipulation of complexity and punctuation provided a stronger manipulation of Hirotani et al.'s study, which found no effect of sentence complexity on sentence wrap up time. Hirotani et al's results supported the claim that wrap-up effects were due to prosody and not discourse integration. Warren et al. combined reading data alongside comparisons of EZ reader simulations (Reichle, Warren & McConnell, 2009), as EZ reader stipulated the integration of words during saccades to the next word (following word recognition). If the reader cannot integrate the prior word with context, then the eyes will not continue into the text, and will either refixate or regress back into the text. Their results and simulations demonstrated longer delays in integration of complex text compared to simpler texts on the critical word with the punctuation after it. An effect of complexity would appear to argue for semantic integration causing sentence wrap-up, as is stipulated in CIM. Warren et al., however, also note that increased reading in wrap-up regions was also found for first fixation duration, an extremely early measure of processing. They argued it was hard to interpret this as a semantic effect, as semantic integration tends to lead to delayed effects. They, therefore, argued that increased first fixation times were a programmed hesitation of the eyes to move beyond a punctuation point, as the reader uses this as a discourse marker to denote the need for integration. In reading, where there is an absence of intonation, punctuation can be used to guide readers' strategies for comprehending what is being communicated.

The explanation provided by Warren et al. (2009) does not appear to be easily integrated with a processing account that is completely dependent on the use of propositional content as units of comprehension, such as CIM. In the next section, theories are discussed that suggest connectives affect readers' interpretation of text immediately, rather than causing suppression and reactivation.

Constraint Satisfaction and Incremental Interpretation

In their paper, Millis and Just (1994) even compared the suppression of first clausal representations in CIM to the suppression observed during the processing of

negated entities (under propositional theory). To reiterate, within propositional accounts, negation is used as a signal to "suppress" semantic information within the negators' scope. There have been theoretical deviations from the propositional account within accounts of the role of connectives in discourse processing, just as there were with accounts of negation processing (as detailed in the Literature Review). Undoubtedly, connectives are important linguistic devices that affect language comprehension. Rather than connectives contributing to discourse representations through suppression and reactivation of text units, more recent explanations have been based on the informative power of the connective (Kuperberg, Paczynski & Ditman, 2011; Murray, 1995; 1997). Within incremental interpretation explanations, connectives offer signals for how to integrate clauses that would otherwise have to be inferred by the reader, a process that takes readers longer (Cozijn, 2001). To recap, incremental interpretation is the notion that a reader adapts their interpretation of text on a word-by-word basis rather than delaying semantic interpretation to the end of text units. The subsequent line of research has investigated the effects different types of connectives have on constraining readers' expectations of the upcoming text. Instead of considering connectives on a propositional level, recent explanations have suggested connectives allow readers to constrain their expectations of upcoming text. The hypothesis generated from an incremental interpretation view was that connectives are processed on a word-by word level, as opposed to the propositional level.

Murray (1995; 1997) investigated adversative, additive and causal connectives and their contribution to readers' instantiation of a discourse representation. As mentioned earlier, additive connectives refer to temporal connectives such as *and,* which do elaborate on the first clause but non-specifically. This is compared to adversative and causal connectives, which specifically denote the type of relation of the two clauses. Murray (1995) initially found adversative connectives led to better memory of text, but slower reading times, compared to text with no connective. Furthermore, causal connectives also led to a small increase in reading times. Murray concluded that these increased reading times were due to readers using connectives as a cue to limit their expectations of the text only to those that match the continuity relation the connective suggested. Delays in reading were, it was suggested, caused by readers 'searching' and providing activation to reasonable

possibilities. Thus, connectives were suggested to be a continuity marker that prompts the reader to build expectancies of the upcoming text.

Murray's (1995) previous study only compared sentences with and without connectives. In Murray's (1997) follow-up experiments, all three types of connective were embedded into the same sentences, consider sentence 5:

5. Manny needed/forgot to publicize the garage sale.

(Consequently/Moreover/However) He arranged flyers to be made

It can be seen how when using the word *forgot*, the second clause is adversative, whereas using the word *needed*, the second clause is causally related. It was predicted, therefore, that incorrect placement of connectives would cause delays in reading during the second clause, if readers were effectively using the connective to limit their expectancies of the unfolding text. Murray found self-paced reading times of the second clause of his stimuli were always faster when the relationship to the first clause matched the relationship each connective denotes, compared to when they did not.

Murray's (1998) findings indicated that readers were effective in using connectives as indicators of the continuity status of the second clause. Causal connectives were taken to indicate a causal continuity, while adversative connectives were indicators of discontinuity between clauses. The fact that shorter reading times were found in the second clause also suggests readers can use connectives to constrain their expectations of upcoming text advantageously. Furthermore, this facilitates processing during the reading of the second clause, as opposed to the reactivation of clauses causing this advantage. Importantly, CIM was unable to explain the finding of increased reading times during reading of the second clause when the connective did not match the continuity of the two clauses. CIM claims that while the first clause representation is suppressed, it cannot affect processing until reactivation. The connective was clearly affecting processing at the point at which the second clause was being reading Murray's study, arguing against a reactivation hypothesis.

Murray (1997) also collected coherence ratings for the experimental sentences, with all three types of connectives. Unsurprisingly, participants rated sentences as less coherent when the connective did not match the continuity of the two clauses. In the case of incongruent additive and causal connectives, however, the effect was weaker, compared to incongruent adversative connectives. One

interpretation was that readers hold a continuity bias when comprehending text. The continuity bias hypothesis stated that as readers move through text, they assume clauses hold a continuous relation, unless otherwise stated. The use of linguistic order of clauses as a method of encoding temporal causality is found in readers from the age of 10, with mastery of adversative relations coming slightly later (Walker-Katz & Brent, 1968). Furthermore, it has been shown that presenting text out of order leads to a processing cost in ERP measures (Munte, Schiltz & Kutas, 1998; Politzer-Ahles, Xiang & Almeida, 2017). For instance, the sentence *before the lumberjacks felled the tree, the men took a break* exhibited a larger processing cost than if the sentence was prefaced with *after,* as the former is out of temporal order. Supporting evidence for the continuity bias hypothesis suggested that readers typically comprehend text as an unfolding series of events, usually presented in temporal order, and set up their expectations of upcoming text as such.

As readers appear to possess a continuity bias, Murray suggested that when an adversative connective is used to show a lack of continuity it makes that content more salient to the reader as it goes against that bias. From aforementioned series of studies, Murray concluded that connectives have an immediate effect on a reader's interpretation of the text. Readers typically expect text to convey an unfolding narrative and it is typically assumed that successive clauses are placed in an order that allows for continuous construction of a stable discourse representation. When a connective is placed between two clauses, it was suggested that they could either confirm this relation, or deny, allowing readers to update their expectations of upcoming text accordingly. As a result, connectives immediately cause readers to constrain their expectations of upcoming text to more reasonable possibilities, given the continuity indicated within a connective.

Traxler and colleagues (Traxler, Sanford, Aked & Moxey, 1997; Traxler, Bybee & Pickering, 1997) continued the trend of looking for immediate processing effects of connectives. In this case, they investigated the differing types of causal nature possible between interlinking clauses. Furthermore, they investigated whether this affected incremental interpretation of text. Support for an incremental interpretation account stems from findings that implausible verb-noun dependencies are immediately detected as such during natural reading (Traxler & Pickering, 1996). For instance, in sentence 6 readers exhibited longer first fixation durations and first pass

reading measured on the verb "*shot"* when the noun *garage* is used due to the implausibility (one cannot conceivably *shoot* someone with a *garage* no matter how heartless they are).

6. *That is the very small pistol/garage with which the heartless killer shot the hapless man.*

The fact the delay occurs immediately upon reading the word that makes the reader's interpretation implausible (*shot*) indicates readers are not delaying semantic integration to the end of a propositional unit. The rapid plausibility effect, as evidence for incremental processing, has been replicated consistently (Clifton, 1993; Stowe, 1989; Trueswell et al., 1994) using eye tracking (Ferguson & Jayes, 2018; Joseph et al., 2009; Rayner et al., 2004; Warren & McConnell, 2007) and with ERPs (Garnsey, Tanenhaus & Chapman, 1989; Nieuwland & Kuperberg, 2008; Nieuwland & van Berkum, 2006) and provides support the notion of incremental interpretation, suggesting that readers constrain their expectations of upcoming text, and update their interpretation of text on a word-by-word basis.

Traxler et al. (1997) drew attention to diagnostic causal statements, which cause a causal relation to become a "psychological event" as any relationship denoted is subject to the inferences made by the communicator. For example, in Sentence 7 it can be see how the diagnostic nature of the text (principally from *I think)* means readers must create a representation of the text as a subjective opinion or belief as the causal relationship is a creation of inference on the part of the communicator.

7. (I think) there are moths in Mary's cupboard because there are holes in her clothes

The causal relation of the argument is, therefore, not definitive and requires readers to make an inference to understand the subjective nature of the causal relationship. Similar to negation and counterfactuals (Anderson et al., 2011, 2012; Ferguson & Sanford, 2008) diagnostic statements have been referred to as mental "space builders" (Fauconnier, 1985) due to their conditional nature. With counterfactuals, readers must instantiate a representation that is in opposition to reality, while maintaining a representation of their real world knowledge (e.g. *cats are not carnivores* instantiates a representation of *a herbivorous cat* while maintaining a real knowledge of a *carnivorous cat;* Ferguson, Scheepers & Sanford, 2010; Ferguson, 2012; Ferguson & Jayes, 2017). With multiple possibility negations, while the text

denotes the absence of one characteristic, it leaves the reader to create multiple possible interpretations (e.g. *the coin is (not) in the air* – it could be anywhere, *the table, the pocket, the hand etc., compared to the coin is (not) heads up* – it must be *tails up;* Anderson et al.; 2010; Huette & Anderson, 2012; Kaup, 2001*).* Similarly, diagnostic statements require readers to embellish their representation to include the inference that there is conjecture on the part of the communicator.

Traxler et al.'s experiment found that simple diagnostic statements (sentence 8) took longer to process than statements with a causal relationship (sentence 9), causing longer reading times for diagnostic statements in their self-paced reading study. The results suggested readers were sensitive to the nature of the causal connective; hence they suffered processing difficulty when the relationship was not as objective as the connective could suggest.

8. *There are moths in Mary's cupboard because there are holes in her clothes.*

9. *There are holes in Mary's clothes because there are moths in her cupboard.*

Increased reading times for diagnostic statements, however, was alleviated they were prefaced with a marker to indicate that the relationship of the statement will not objectively be *A causes B* but rather *A because B.* For example, in sentence 7 *I think* acts as an epistemic marker which signals to the reader that the incoming text can be captured as someone's inference. The epistemic marker updates a readers' incremental interpretation to instantiate a mental space within which this inference can be understood as quickly as simple causal statements. The relieving effect of the epistemic marker provides support for the notion that readers are sensitive to different types of connectives and the causal relations between clauses. Furthermore, this sensitivity affects on-line text comprehension.

Furthermore, Traxler et al. (1997) analyzed eye movement measures during reading to understand the time course within which diagnostic statements are processed. They used diagnostic statements (sentence 11) and a causal equivalent (sentence 10) to understand the timecourse of the delay found by Traxler et al. (1997).

10. *Heidi felt very proud and happy because she won first prize at the art show.*

11. *Heidi could imagine and create things because she won first prize at the art show.*

Unlike with sentence 10 it can be seen that the first clause of sentence 11 is not directly responsible and causal to the second. Instead, an inference must be made, on the part of the reader, that the second clause is being used as evidence for the first.

The delayed integration hypothesis from Just and Millis' (1994) CIM would have predicted that a delay in comprehending sentence 11 would not occur until the end of the second clause during sentence wrap-up. The late delay would be due to the first clause being held in an auxiliary processing system until the second clause has been interpreted. Once the second clause had been read, the two clauses could then be integrated with their diagnostic causal relationship. A delay compared to sentence 10 would have still been predicted within CIM due to the extra inference that needs to be made to understand how the communicator is establishing a relationship without direct evidence. The main difference between CIM and incremental interpretation stems from the timecourse of the delay.

Traxler et al. (1997) found the delay for diagnostic sentences occurred midway through reading of the second clause, with more regressions back into the text as well as longer first-pass and total reading times. Readers were, presumably, incrementally interpreting the text, thus the connective *because* constrained readers to expect a causal relationship in the incoming text. When a diagnostic conditional was represented, readers needed to stop moving forwards in the text, and allow for semantic reanalysis of the text to understand the non-direct relationship shared between the two clauses. This study very clearly showed that the information from the first clause, and the connective itself, have effects on incremental interpretation of text. Specifically, connectives constrain readers' expectations of incoming text by indicating whether the next clause will share a continuous relation with the previous clause or not.

More recent research from Canestrelli, Mak and Sanders (2013) attempted to show how pragmatic knowledge affects understanding of subjective and objective connectives. In Dutch, subjectivity of the causal connective *because* is actually encoded into the two lexical items the Dutch language possess for this word. Both *want* and *omdat* translate into *because. Omdat,* however, would be used in a sentence such as 12, where the relation is objective, while *want* would be used in a sentence such 13, where the relation is subjective, as it requires inferences about the communicator's mental state. This distinction between two causal connectives has

been observed in French (*parce que* and *pauisque*, Zufferey, 2011), German (*weil* and *denn,* Pasch, 1983), Latin (Kroon, 1998) and Mandarin Chinese (Xing, 2001) among others. It draws an interesting comparison to the work of Traxler and colleagues (Traxler, Sanford, Aked & Moxey, 1997; Traxler, Bybee & Pickering, 1997) who encoded this information through context in English, whereas other languages can differentiate and encode subjectivity within the lexical items themselves using different connectives.

12. *Peter stays home because he is ill.*

13. *Peter must be ill because he looks pale.*

The authors predicted that readers use connectives to constrain their interpretation of the subjectivity of the causal relationship dependent on whether *omdat* or *want* is used. Their eye movement results replicated Traxler, Sanford, Aked and Moxey's (1997) findings that when readers must infer that the relationship between two clauses is subjective, reading times increase. Reading delays were found earlier, however, as Dutch readers were able to interpret the subjective nature of the text at the point of the connective. Hence, reading delays were found from the point of the subjective connective onwards. Furthermore, the increase in reading times was alleviated when the subjective statement is prefaced with an epistemic marker (*John thought…),* as it constrained readers' interpretation of causality to one that has been subjectively judged. Finally, they found that when *omdat* was placed in a subjective statement, and *want* in an objective, reading was disrupted during reading of the second clause. The authors took this to show that readers are responsive to the pragmatic nature of a connective and use them to constrain their expectations of incoming text. Once again, the differences between two connectives' semantic properties had an immediate influence on online processing of the text. When this influence is shown to be misleading or incorrect, it impedes normal reading as readers attempt to correct their semantic interpretation.

Similarly, Mak, Tribushinina and Andreiushina (2014) have also found readers are sensitive to the semantic properties of connectives in Russian. In this case, different connectives are used for the connective *and* dependent on whether the subsequent clause will maintain focus on the referent from the previous clause, or shift to a different referent (*a* and *I* respectively). Using the visual world paradigm, in Russian, they found participants were quicker to fixate appropriate referents at the

point at which they heard the connective. To be clear, upon hearing *a*, readers maintained their gaze on the referent from the previous clause. In contrast, upon hearing *I,* readers fixated other referents on the screen, anticipating a reference shift before it occurred. Readers must, therefore, have been taking this information from the use of the connective. This provides further evidence for the informative power of the connective in constraining readers' expectations of upcoming text.

Kohne and Demberg (2013) compared negations' impact on incremental processing to that of concessive connectives, such as *however*. Concessive connectives contrast two clauses with the second usually being surprising or unexpected, and are considered in this way to be negative (Konig & Siemund, 2000). Kohne and Demberg's visual world study presented participants with several items while listening to sentences such as 14, which features either a causal or concessive connective.

> 14 (translated from German). *Mark fancies a snack. He feels like having something* ***sweet****. Therefore/Nevertheless he gets from the kitchen the delicious cake/pretzel.*

Kohne and Demberg's eye movement data indicated that participants fixated suitable exemplars after hearing the word *sweet* and would then fixate suitable exemplars at the point of hearing the connective. The interpretation they took was that comprehenders engaged in rapid encoding of the connective and the relationship to previous context, regardless of the continuity of that relationship. If the comprehender heard *nevertheless,* they were more likely to fixate on *savory* exemplars, suggesting rapid interpretation of the connective and subsequent prediction of discourse. In an eye tracking and reading experiment using the materials of experiment 1, it was found that there was no significant delay to reading when the concessive connective did not match previous context. Rather than being due to a lack of processing of the connective, the authors argued it is due to the inherent ambiguity of the concessive connective. While causal connectives have a direct cause and effect relationship, this is not the case with concessive relationships. Instead, the scope is much more ambiguous, as it could be referring to the previous clause or the next. As the authors note in the case of 15:

> 15. *I want to do A and B. A is more important, however/because…*

If there is a causal relationship (*because*) it is extremely likely that the next clause will refer to A. In the case of the concessive (*however*), it is possible for the next

clause to refer B, or C (e.g. *However, there is also C).* Through this example it can be seen how the scope of concessive connectives is much more ambiguous, as the next clause could be referring to the previous clause or the next. Nevertheless, readers are clearly interpreting connectives at the point at which they read them and constraining their expectancies accordingly.

In summary, different connectives place different constraints on readers' expectancies of upcoming text. When the readers' expectancy is met, facilitation of language processing has been found, when text does not meet the readers' expectancy, disruption to reading had been found. Research clearly indicates the informative power of a connective on a reader's incremental interpretation of relationships between the last clause and the next (Murray, 1997). Furthermore, while an objective causal connective may be the easiest to process in terms of speed (Cozijn, 2001; Kuperberg, Paczynski & Ditman, 2011), in isolation, other markers have been show to facilitate the expectation of a subjective/diagnostic connective (Canestrelli et al., 2013; Traxler et al., 1997). Contrary to Millis and Just's (1994) propositionally based CIM of connective clausal interpretation, readers incrementally interpret connected statements, updating their discourse representation word-by-word, and placing importance of connectives as linguistic operators.

Experiment 3: The Effect of Connectives upon the Processing of Bounded and Unbounded Negation

Through the use of eye movement measures during reading, the results of Experiment 2 provided evidence that readers are sensitive to boundedness during on-line processing of text. The aim of Experiment 3 was to investigate whether connectives can facilitate the representation of negation, and whether this process is moderated by boundedness. In Experiment 3, continuous connectives were inserted into the passages of Experiment 2, in order to investigate whether connectives can alleviate the processing difficulty previously found in the reading of these passages. An eye movement experiment was carried out using the passages from Experiment 2. The three types of bounded and unbounded passages used were repetition passages (*not alive – not alive),* incongruent passages *(not alive-not dead)* and complementary passages *(alive – not dead* – see Table 4.1). In the repetition and complementary case,

causal connectives were used, as the two antonym usages are congruous with each other. In the incongruent condition, adversative connectives were used, as the two antonym usages are incongruous with each other. In Experiment 3 the results from Experiment 2 were also considered and included in a meta-analysis to assess the effect of connectives on the reading of passages featuring bounded and unbounded negation.

Table 4.1. Regions of interest in the (i) bounded repetition, incongruent, complementary and (ii) unbounded repetition, incongruent and complementary conditions.

Region of Interest	Text
(i) Licensing Context	Rushing into the emergency room, the doctor and the nurse were talking about one of their cases.
First Antonym Use	The doctor stated clearly that the patient was (not) **alive**.
Connective	Therefore/However,
Repetition Sentence	the nurse declared that the patient was | not | **alive** | and noted it down in her paperwork. |
Incongruent Sentence	the nurse declared that the patient was | not | **dead** | and noted it down in her paperwork. |
Complementary Sentence	|the nurse declared that the patient was | not | **dead**| and noted it down in her paperwork. |
Wrap-Up Sentence	| Great care was taken to regularly check the condition of all the patients. |
(ii) Licensing Context	The boss was checking his new employee's attendance record with his secretary.
First Antonym Use	The boss was quite sure the employee was (not) **early**.
Connective	Therefore/However,
Repetition Sentence	Following her orders, the secretary noted in her records that the employee was | not | **early** | for work today. |
Incongruent Sentence	Following her orders, the secretary noted in her records that the employee was | not | **late** | for work today. |
Complementary Sentence	Following her orders, the secretary noted in her records that the employee was | not | **late** | for work today. |
Wrap-Up Sentence	| It was the secretary's job to maintain employee records. |

Hypotheses

Bounded Complementary Passages

In terms of predictions, for the bounded complementary condition, previously (in Experiment 2) an immediate, but very transient, delay in reading was found before a swift return to normal reading. Presumably, readers already had one representation (e.g. *alive*) that was semantically similar and easily integrated with the negated item (*not dead*). With the presence of a connective, readers should already have constrained their representation to expect a complementary referent. Furthermore, integration of bounded complementary antonyms occurs relatively early in processing. Previous studies of negation have also suggested bounded negation to be represented very quickly (Anderson, et al., 2011; Du et al., 2014; Paradis & Willners, 2006). This is because bounded negation is unambiguous and, therefore, can be interpreted very quickly. As a result, it was predicted that the connective would facilitate early stages of processing. The connective should allow for facilitatory integrative processing following the successful instantiation of the negated representation, which is processed very rapidly in bounded, unambiguous cases. It was predicted, therefore, that this facilitation would manifest in early eye movement measures when encountering the second antonym in the bounded complementary condition.

Unbounded Complementary Passages

In the unbounded complementary condition in Experiment 2, disruption occurred to reading, which persisted past the target region, but not to the end of the passage. Unbounded negation is ambiguous and not considered to be semantically similar to its antonym. As such, readers showed delays in reading as they underwent a degree of inferential processing to establish a conciliatory representation of an unbounded negation and its antonym. In contrast to the early processing facilitation expected in bounded complementary passages, facilitation of slightly lately measures of processing was predicted for unbounded complementary passages. Once this ambiguity has been overcome, the connective should allow for a facilitation of integrative processing. Previous studies of negation have also suggested unbounded negation to be represented more slowly (Anderson et al., 2011; Du et al., 2014; Paradis & Willners, 2006). This is because unbounded negation is ambiguous and,

therefore, cannot be interpreted quickly. Once represented, however, the negation can be rapidly integrated with previous discourse, as the connective already signals to the reader that there is equivalence between the two statements. It was predicted, therefore, that with the presence of a connective, facilitatory effects would be found in later eye movement measures from the point at which readers reached the target region in the unbounded complementary condition.

Bounded Incongruent Passages

In the bounded incongruent condition in Experiment 2, there were early and lasting delays to reading as the negation could be quickly interpreted but not logically integrated with previous discourse. Readers showed difficulty in instantiating a representation of a man who was both *not dead* and *not alive*. As these stimuli lack epistemic markers, the negations are presented as fact rather than based on the mental state of a character. The connectives do not remove the logical contradiction from discourse; they just indicate that it will occur, as the adversative connective indicates discontinuity between the two negations. It was predicted, therefore, that even with a connective, the logical contradiction within bounded incongruent passages would still cause lasting disruption to eye movement measures.

Unbounded Incongruent Passages

In the unbounded incongruent condition in Experiment 2, readers suffered disruption to processing that ended before the final sentence of the passage. Presumably, once participants had inferred a state that existed outside of the mutual mutually non-exhaustive antonyms (e.g. the state of *on time* exists between *not early* and *not late*), reading could continue typically. There is an inherent ambiguity present in unbounded utterances. As such, it could be predicted that at the point at which readers fixate the connective, they will not be able to effectively constrain their expectations of upcoming text. As the first unbounded negation has not denoted an explicit state, readers will struggle to build up expectations of upcoming text, unlike in the bounded case. It was predicted that the presence of a connective would should lead to faster reading times for the unbounded incongruent passages. The connective does match the continuity status of the two negations; meaning it should still provide

facilitation during integrative processing. This, however, would occur quite late in processing due to the lack of constraint provided by unbounded negation. It was predicted, therefore, that the connective indicates to readers that the two negations can be integrated into a single representation. Unlike in the bounded incongruent condition, this is the case in the unbounded condition.

In summary, in Experiment 3 the stimuli from Experiment 2 were adapted with the placement of a connective between the two antonym usages. Another eye movement experiment was run, with the results compared to those in Experiment 2. In this manner, it was possible to investigate whether the inclusion of a connective can alleviate processing difficulty that arises from reading the bounded and unbounded passages.

Experiment 3: Methodology

Participants

Seventy-two participants (57 females) with a mean age of 20.2 (range 18-42) were recruited from the University of Southampton and took part for course credit or a small cash payment (£6/hour). All participants were native English speakers and reported normal or corrected to normal vision and no known reading problems.

Materials and Design

A 2x3x2 design was used, with the factors of boundedness (bounded, unbounded) and passage type (repetition, incongruent, complementary) manipulated. Furthermore, the present data were compared with those of Experiment 2, in order to see if there was an effect of connective presence (presence of connective vs. no connective). The variable of markedness was not considered within Experiment 3, due to its lack of effect on any measures in Experiment 2. Instead, polarity was counterbalanced across items.

The passages from Experiment 2 were used. These materials consisted of 72 passages within which two characters discussed a referent using bounded or unbounded antonyms (36 bounded and 36 unbounded). A connective was placed between the two antonym usages. Regions of interest can be seen in Table 4.1.

Items were divided into three stimulus lists, containing all 72 bounded and unbounded stimuli, with passage type counterbalanced over the lists using a Latin square design. Each of the lists contained an additional 72 filler items, which were of a similar length to the experimental items. Materials were presented to participants across four to seven lines in a double spaced format.

Procedure

Procedure was the same as used in Experiment 2. The only addition was the use of an Eyelink 1000+ eye tracker.

Experiment 3: Results

Data exclusions matched those used in Experiment 2. These exclusions accounted for 5.5% of the data. Prior to data analysis, data for each eye movement measure that were more than 2.5 standard deviations from the condition mean for each participant were removed (affecting <1% of dataset). Data loss affected all conditions similarly (i.e. no differences across conditions, all ts<1). Across participants, 89% of the comprehension questions were answered correctly with no differences observed across conditions (all ts<1).

Analyses

Data analyses was the same as in Experiment 2, with the addition of connective use as a fixed factor in the models, with data used from both the current experiment and Experiment 2. An interaction term was also placed between passage type and connective type. Successive difference contrasts were used, such that the intercept corresponds to the grand mean, fixed factor estimates can be interpreted as the difference between two conditions (corrected Holm-corrected significance values). As in Experiment 2, bounded and bounded regions were analysed separately. The means and standard deviations of all six measures across all four regions can be found in Table 4.2.

Regions and Measures

We analysed the same five reading measures of reading, seen in Experiment 2, across four regions of interest. See 3 and 4 for the LME analyses of these measures. See previous chapters for discussions of these variables.

Pre-Target Region

No effects or interactions were found for the analysis of the region prior to the experimentally manipulated target region.

Target Region

For first fixation duration and gaze duration (See Table 4.3 and 4.4), there was a main effect of passage type in both the bounded and unbounded datasets, where first fixations and gaze durations were longer on the target in the incongruent condition, compared to the repetition condition. There was also a main effect of connective presence in both the bounded and unbounded datasets, with shorter first fixations and gaze durations when a connective was present compared to absent. In the bounded dataset, these main effects were qualified by an interaction between passage type and connective presence.

For the interaction on first fixation (see Figure 4.1), when a connective was present, no difference between the bounded incongruent and bounded complementary conditions was observed (b =-5.89, t = 1.76). When a connective was absent, however, a readers' first fixation on the target was longer in the incongruent condition compared to the complementary (b = 8.26, t = 2.48). This suggests early facilitation of a very early measure related to negation processing in the bounded complementary condition, when a connective was provided.

For the interaction on gaze duration (see Figure 4.2), when a connective was absent, no difference between the bounded incongruent and bounded complementary conditions was observed (b = 8.05, t = 1.56). When a connective was present, however, readers gaze durations on the target were longer in the incongruent condition compared to the complementary (b = 11.18, t = 2.15). No interactions were present in the unbounded dataset. As both measures are indices of

early processing, taken together, they suggest early facilitation of negation processing in the bounded complementary condition when a connective was present. No early facilitatory effects were found for the unbounded complementary target words.

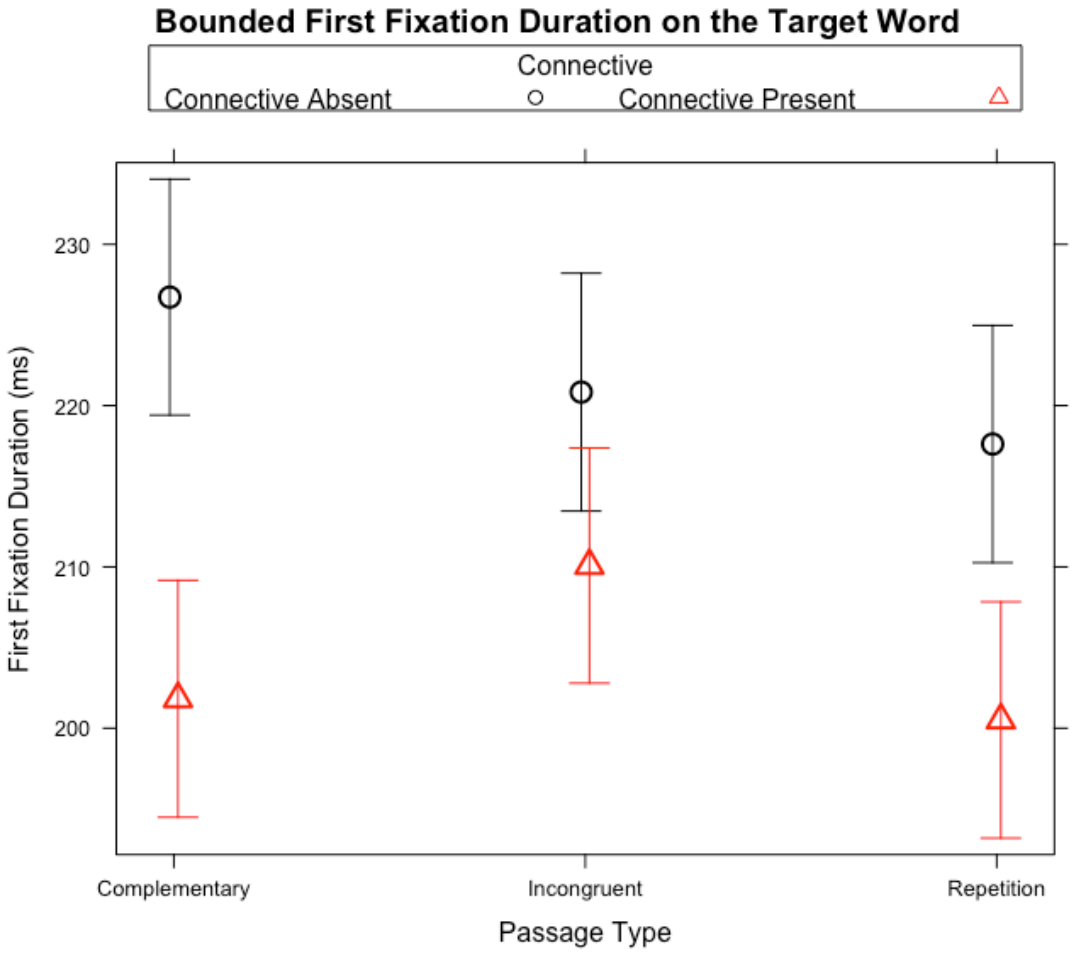

Figure 4.1. Two-way interaction between experiment and passage type for first fixation durations on the bounded target word. Means and standard error bars.

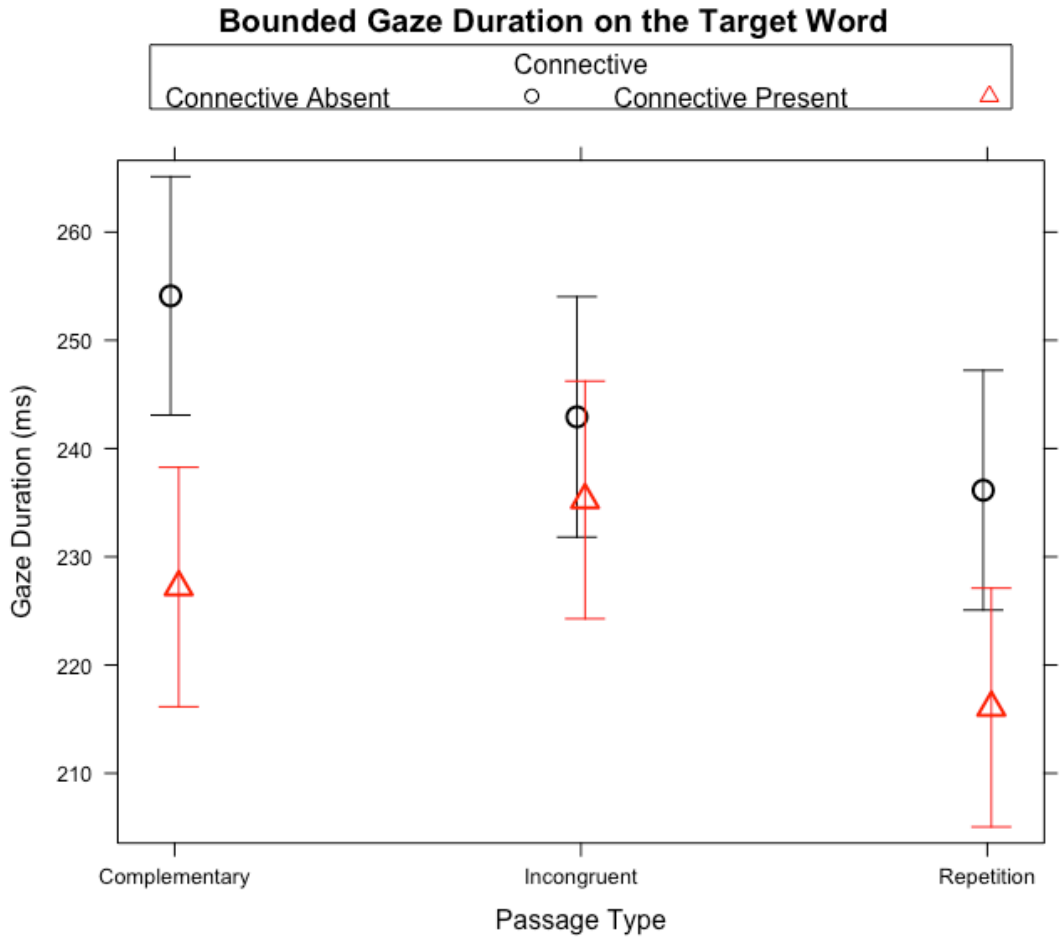

Figure 4.2. Two-way interaction between experiment and passage type for gaze durations on the bounded target word. Means and standard error bars.

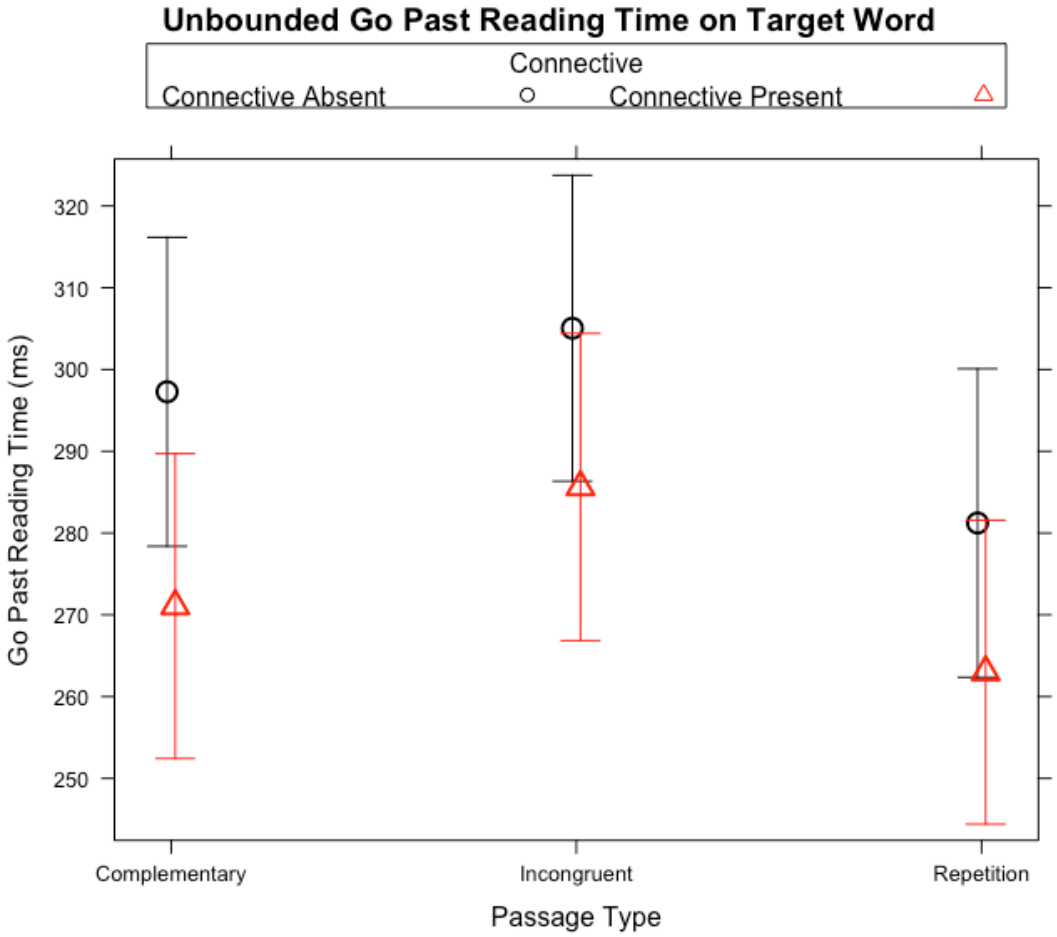

Figure 4.3. Two-way interaction between experiment and passage type for go past reading times on the unbounded target word. Means and standard error bars.

For go-past reading time (See Table 4.3 and 4.4), there was a main effect of passage type in both the bounded and unbounded datasets, where go-past reading time was longer on the target in the incongruent condition compared to the repetition condition. In the unbounded dataset, go-past reading time was also significantly shorter in the complementary condition compared to the incongruent condition. There was also a main effect of connective presence in both the bounded and unbounded datasets, go-past reading time was shorter when a connective was present compared to absent. In the unbounded dataset, these main effects were qualified by an interaction between passage type and connective presence (see Figure 4.3). There was no difference between go-past times in the repetition and complementary conditions with a connective absent (b = 8.08, t = 1.02). Unbounded complementary targets, however, received longer go-past times than repetition targets (b = 16.05, t = 1.95). No interactions were present in the bounded dataset.

This later measure of processing appears to show facilitation only in the unbounded complementary condition.

For total reading time on the target word, there were main effects of passage type in both the unbounded and bounded conditions. In the bounded case, the incongruent condition yielded longer total reading times than both the repetition and complementary condition. Furthermore, complementary condition yielded longer total reading times than the repetition condition. In the unbounded case, incongruent and complementary conditions yielded longer total reading times than the repetition condition, but did not significantly differ from each other.

For regressions out (See Table 4.3 and 4.4), a main effect of passage type was found for the bounded conditions, with incongruent passages causing more regressions from the target than the repetition condition. No main effects were found in the unbounded conditions, but there was an interaction between connective presence and passage type (see Figure 4.4). Planned contrasts showed when a connective was absent, there were no significant differences of regressions out of the target region between the complementary and repetition condition (b = -0.03, t = 1.18). When a connective was present, fewer regressions were launched from the complementary condition, relative to the incongruent condition (b = 0.05, z = 2.23), indicating facilitation of the complementary condition when a connective was present. As the latter measures are indices of later processing, taken together, they suggest there was late facilitation of negation processing in the unbounded complementary condition when a connective was present.

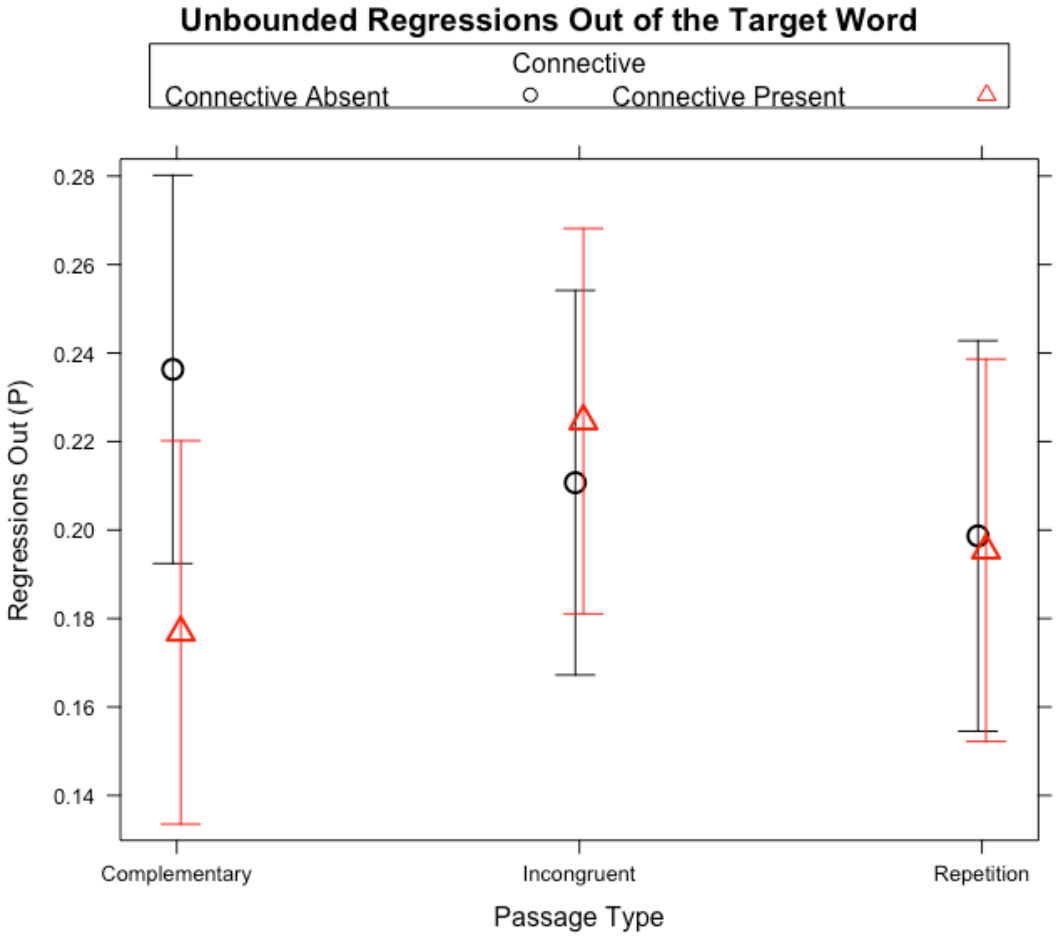

Figure 4.4. Two-way interaction between experiment and passage type for regressions out of the unbounded target word. Means and standard error bars.

The results of the target analyses indicate the connective provided a general facilitation to reading, with main effects in all reading time measures on the target. This means participants read the target word of the passages faster when a connective was present within the text, suggesting a general facilitation to reading when readers are supplied with an explicit continuity marker. Early facilitation was found during the reading of bounded complementary passages with a connective present. Facilitation was found within first pass reading of the target word (fixations during the initial reading of the text before making an eye movement away from this region, specifically, in first fixation and gaze duration). In contrast, facilitation was found in the later measure of go-past time for unbounded complementary passages with a connective present. As this measure includes fixations into earlier regions of text (re-reading of previous content), it is suggested to be a 'later' measure of

language processing (Liversedge et al., 1998). The results provide no evidence to suggest any facilitatory influence from connectives for the reading of both bounded and unbounded incongruent passages.

Post-Target Region

There were main effects of connective presence in the bounded and unbounded dataset for first pass reading time, total reading time and go-past reading time (See Table 4.3 and 4.4). Specifically, shorter reading times were observed for all of these measures when a connective was present compared to when a connective was absent. For go-past reading time, there was also a main effect of passage type, such that bounded incongruent and bounded complementary passages received longer go past reading times, compared to the bounded repetition condition. For total reading time, there was also a main effect of passage type, such that unbounded incongruent and unbounded complementary passages received longer total reading times, compared to the unbounded repetition condition. For regressions out, there was also a main effect of passage type in both the bounded and unbounded analyses. In both cases, incongruent and complementary passages received longer total reading times, compared to the repetition condition.

In the bounded dataset, this main effect was qualified by an interaction of connective presence and passage type in the regressions out measure (see Figure 4.5). Planned contrasts showed more regressions out of the complementary condition than the repetition condition when a connective was absent (b = 0.07, z = 3.64); the difference was not found when a connective was present (b = 0.02, z = 1.09). For total reading time, there was also a main effect of passage type, such that unbounded incongruent passages received longer total reading times, compared to the unbounded repetition condition.

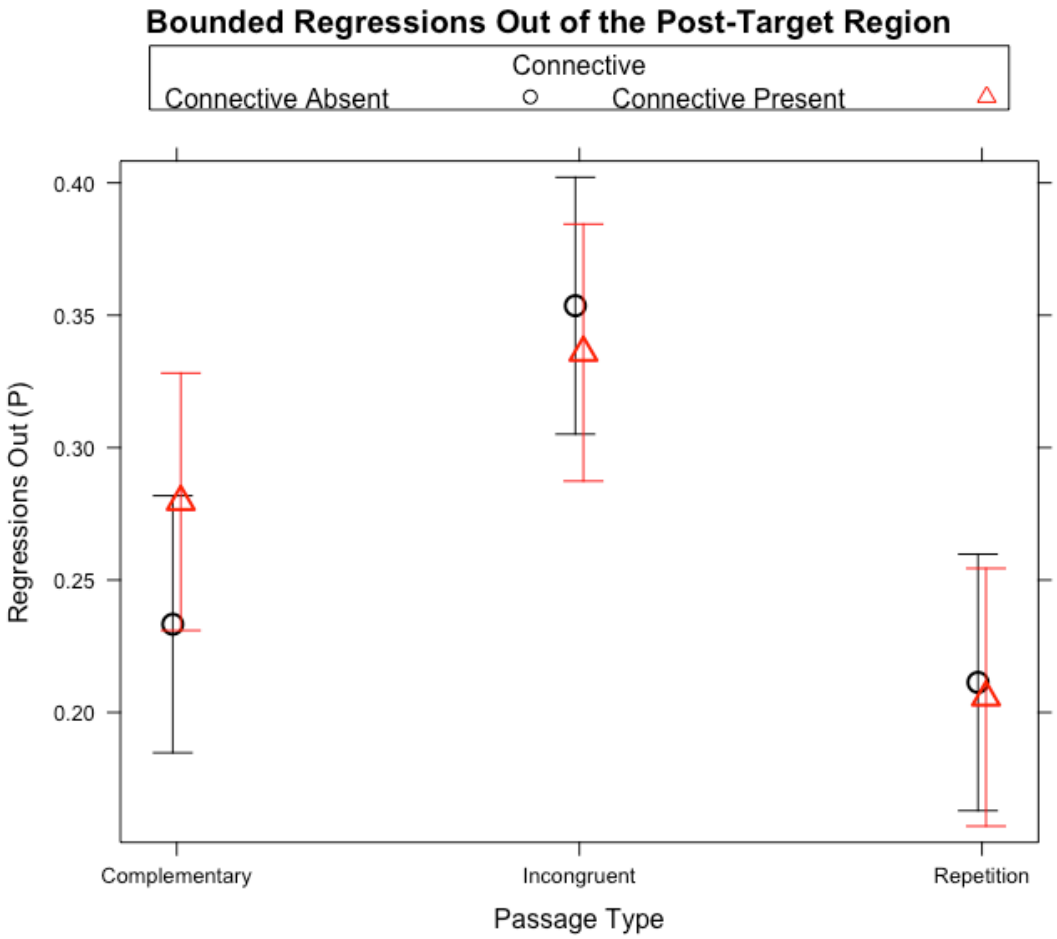

Figure 4.5. Two-way interaction between experiment and passage type for regressions out of the bounded post target region. Means and standard error bars.

Wrap-Up Region

There were main effects of connective presence in the bounded and unbounded dataset for first pass reading time, total reading time and go-past reading time, with shorter reading times when a connective was present, compared to when a connective was absent. In the bounded dataset, the above main effect was qualified by an interaction of connective presence and passage type for first pass reading time (see Figure 4.6). Planned contrasts, however, found no significant differences between the repetition and incongruent when a connective was present (b = 50.02, t = 1.84) or when a connective was absent (b = 40.34, t = 1.45). In the unbounded dataset, the main effect of total reading time was qualified by an interaction of connective presence and passage type (see Figure 4.7). Planned contrasts showed total reading times for the complementary condition were shorter compared to the

incongruent condition when a connective was absent (b = 95.48, t = 3.52), this difference was not found when a connective was present (b = 11.23, t = 0.43). This final interaction indicates more late facilitation to reading in the unbounded complementary condition, compared to the unbounded incongruent condition.

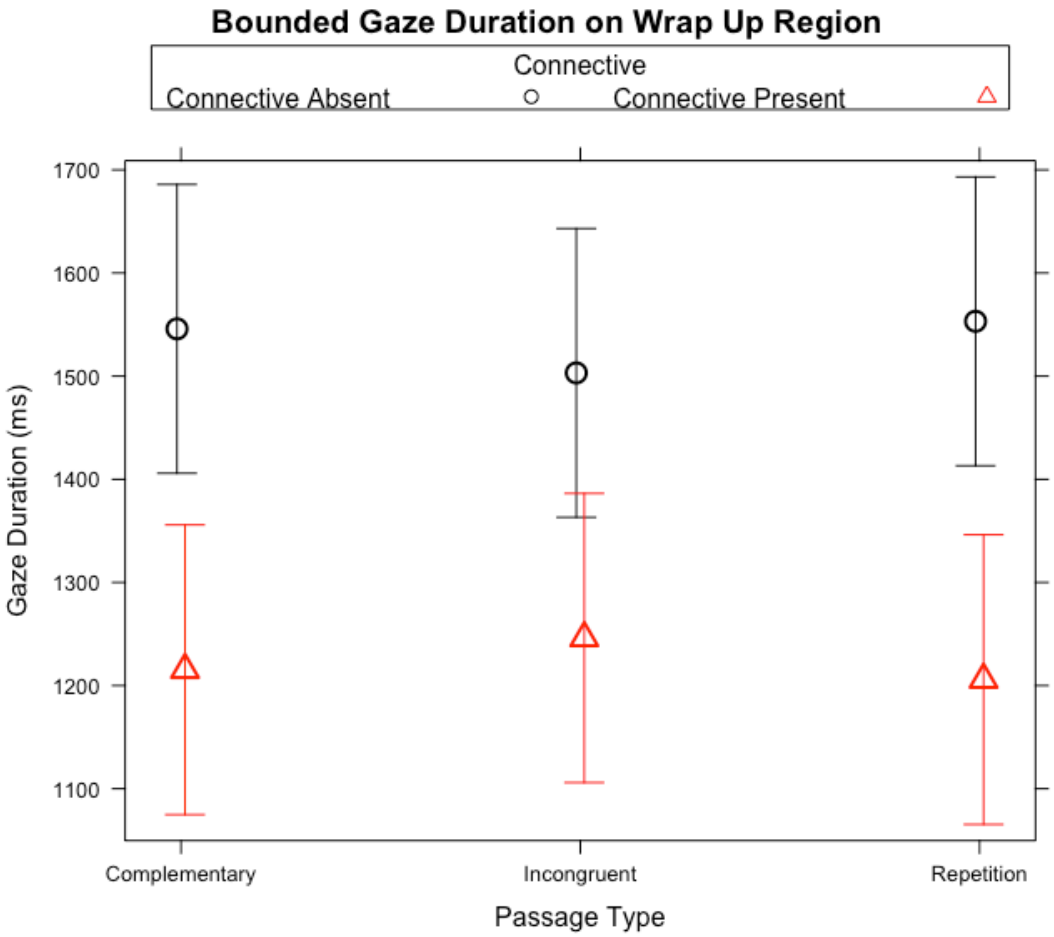

Figure 4.6. Two-way interaction between experiment and passage type for first-pass reading time on the bounded wrap up region. Means and standard error bars.

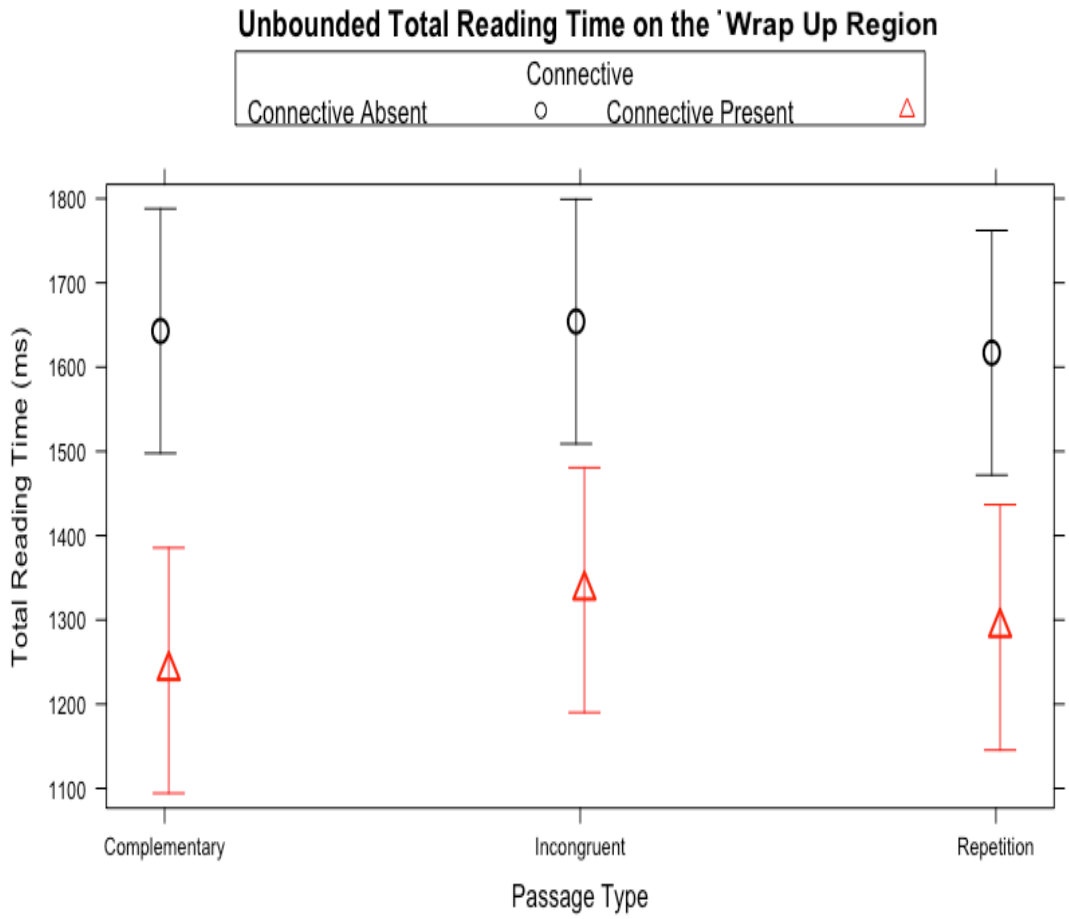

Figure 4.7. Two-way interaction between experiment and passage type for total reading time in the unbounded wrap up region. Means and standard error bars.

Table 4.2. Mean fixation times and regression rates for the four regions of interest.

		Pretarget Region		Target Region		Post Target Region		Wrap Up Region	
		M	SD	M	SD	M	SD	M	SD
First Fixation Duration	Bounded Repetition	204	60	200	49	204	64	177	67
	Bounded Incongruent	212	63	210	55	215	73	177	66
	Bounded Complementary	201	57	202	58	214	69	180	68
	Unbounded Repetition	200	56	198	49	211	89	181	71
	Unbounded Incongruent	207	61	208	57	279	78	178	67
	Unbounded Complementary	200	56	206	53	267	70	179	65
Gaze Duration/First Pass Reading Time	Bounded Repetition	214	70	217	65	459	244	1218	591
	Bounded Incongruent	223	72	235	87	478	251	1252	616
	Bounded Complementary	213	68	227	86	454	243	1231	647
	Unbounded Repetition	207	62	217	70	422	209	1233	638
	Unbounded Incongruent	212	64	235	84	435	228	1251	631
	Unbounded Complementary	208	58	231	80	415	212	1192	601
Go-Past Reading Time	Bounded Repetition	247	102	264	99	598	341	1423	771
	Bounded Incongruent	259	111	301	140	733	407	1595	808
	Bounded Complementary	248	108	287	133	655	382	1446	788
	Unbounded Repetition	235	80	263	115	568	326	1404	757
	Unbounded Incongruent	234	94	285	124	719	415	1451	724
	Unbounded Complementary	240	85	275	118	606	372	1378	701
Total Reading Time	Bounded Repetition	275	164	251	99	533	282	1292	602
	Bounded Incongruent	318	189	315	140	615	301	1377	598
	Bounded Complementary	328	204	281	133	555	290	1315	636
	Unbounded Repetition	295	179	251	105	494	254	1299	646
	Unbounded Incongruent	337	199	298	134	565	249	1337	631
	Unbounded Complementary	317	179	271	116	509	267	1268	595
Regressions Out	Bounded Repetition	0.09	0.19	0.18	0.28	0.21	0.35	0.18	0.32
	Bounded Incongruent	0.08	0.17	0.23	0.35	0.33	0.44	0.4	0.4
	Bounded Complementary	0.08	0.19	0.23	0.35	0.28	0.4	0.33	0.33
	Unbounded Repetition	0.06	0.14	0.17	0.32	0.24	0.41	0.18	0.34
	Unbounded Incongruent	0.07	0.16	0.19	0.35	0.38	0.46	0.24	0.36
	Unbounded Complementary	0.07	0.14	0.15	0.27	0.27	0.41	0.18	0.33

*Table 4.3. Fixed effect estimates from linear mixed-effects models for all measures across all regions of interest from the bounded dataset. * t >1.96.*

		Target Region		Post Target Region		Wrap Up Region	
		Estimate	*t* value	Estimate	*t* value	Estimate	*t* value
First Fixation Duration	Intercept	200.51	53.66*	-	-	-	-
	Main effect of incongruent Condition	9.58	2.89*	-	-	-	-
	Main effect of complementary condition	1.32	0.39	-	-	-	-
	Main effect of connective	17.11	3.45*	-	-	-	-
	Interaction of incongruent condition and connective	-6.36	1.34	-	-	-	-
	Interaction of complementary condition and connective	7.80	2.30*	-	-	-	-
Gaze Duration/ First Pass Reading Time	Intercept	243.57	56.18*	462.72	13.62*	1207.11	16.18*
	Main effect of incongruent Condition	-15.27	4.13*	18.76	1.31	39.17	1.25
	Main effect of complementary condition	-1.24	0.34	-3.71	0.25	8.61	0.22
	Main effect of connective	18.63	3.19*	138.97	4.82*	346.57	5.55*
	Interaction of incongruent condition and connective	-12.24	1.65	-18.48	-0.94	-89.93	2.29*
	Interaction of complementary condition and connective	15.37	2.09*	2.88	0.15	-16.84	0.37
Go-Past Reading Time	Intercept	310.14	32.41*	771.03	20.90*	1667.12	21.58*
	Main effect of incongruent Condition	53.54	6.75*	192.80	8.34*	147.00	5.01*
	Main effect of complementary condition	-24.50	3.10*	-146.13	7.13*	-145.81	4.96*
	Main effect of connective	26.34	2.04*	182.88	4.96*	311.71	3.85*
	Interaction of incongruent condition and connective	-19.21	1.21	24.78	0.57	-107.74	1.83
	Interaction of complementary condition and connective	3.09	0.20	-18.47	-0.45	96.85	1.65
Total Reading Time	Intercept	208.36	20.54*	529.94	42.50*	1450.53	66.43*
	Main effect of incongruent Condition	57.43	7.51*	6.72	0.51	69.79	2.67*
	Main effect of complementary condition	24.42	3.21*	12.80	0.94	5.28	0.20
	Main effect of connective	62.99	5.10*	-10.88	0.62	323.16	7.40*
	Interaction of incongruent condition and connective	-3.03	0.27	-6.09	0.30	77.96	1.49
	Interaction of complementary condition and connective	-1.90	0.17	5.73	0.56	-25.05	0.48
Regressions Out	Intercept	-1.54	13.55*	-1.16	11.33*	-1.78	11.94*
	Main effect of incongruent Condition	0.33	3.25*	0.78	9.37*	0.62	4.85*
	Main effect of complementary condition	-0.19	1.89*	-0.49	6.02*	0.05	0.36
	Main effect of connective	0.09	0.57	-0.03	-0.25	0.30	1.61
	Interaction of incongruent condition and connective	-0.15	-0.72	0.04	0.22	0.32	-1.82
	Interaction of complementary condition and connective	-0.22	1.11	-0.35	2.20*	-0.09	-0.50

Table 4.4. Fixed effects estimates from linear mixed-effects models for all measures across regions of interest from the unbounded dataset, t > 1.96.

		Target Region		Post Target Region		Wrap Up Region	
		Estimate	*t* value	Estimate	*t* value	Estimate	*t* value
First Fixation Duration	Intercept	216.15	85.83*	-	-	-	-
	Main effect of incongruent Condition	11.90	4.57*	-	-	-	-
	Main effect of complementary condition	-3.31	1.27	-	-	-	-
	Main effect of connective	17.95	3.90*	-	-	-	-
	Interaction of incongruent condition and connective	-1.13	0.22	-	-	-	-
	Interaction of complementary condition and connective	5.05	0.97	-	-	-	-
Gaze Duration/ First Pass Reading Time	Intercept	236.90	60.92*	424.40	14.80*	1206.63	16.07*
	Main effect of incongruent Condition	18.24	4.96*	24.14	1.88	42.62	1.13
	Main effect of complementary condition	-6.94	1.89	-0.27	-0.02	-45.83	1.51
	Main effect of connective	12.63	2.04*	99.28	4.23*	311.47	4.84*
	Interaction of incongruent condition and connective	-3.52	0.48	0.02	0.00	18.49	0.45
	Interaction of complementary condition and connective	0.60	0.08	13.39	0.79	78.70	1.93
Go-Past Reading Time	Intercept	296.29	40.24*	708.41	22.61*	1470.59	16.83*
	Main effect of incongruent Condition	33.99	4.93*	180.77	11.90*	50.11	0.85
	Main effect of complementary condition	-14.17	2.06*	-130.41	8.58*	-98.65	2.07*
	Main effect of connective	24.34	2.11*	153.02	4.61*	352.03	3.90*
	Interaction of incongruent condition and connective	2.69	0.20	45.78	1.51	13.20	0.18
	Interaction of complementary condition and connective	27.39	1.99*	-27.73	0.91	75.24	1.15
Total Reading Time	Intercept	249.65	25.93*	579.22	19.40*	1454.72	21.06*
	Main effect of incongruent Condition	48.32	6.39*	97.14	10.24*	44.69	2.21*
	Main effect of complementary condition	21.38	2.85*	-52.94	5.58	-57.46	2.84*
	Main effect of connective	14.65	1.22	143.14	5.47*	405.65	6.51*
	Interaction of incongruent condition and connective	11.08	1.03	31.45	1.66	-39.13	0.97
	Interaction of complementary condition and connective	10.97	1.02	1.02	0.05	103.90	2.57*
Regressions Out	Intercept	-1.55	15.99*	-0.95	10.06*	-1.76	10.88*
	Main effect of incongruent Condition	0.14	1.38	0.81	10.07*	0.38	2.86*
	Main effect of complementary condition	-0.09	0.86	-0.58	7.40*	0.03	0.25
	Main effect of connective	0.13	0.81	0.03	0.24	0.30	1.59
	Interaction of incongruent condition and connective	-0.11	0.54	0.16	0.99	-0.11	0.62
	Interaction of complementary condition and connective	0.50	2.45*	-0.02	0.16	-0.12	0.67

Experiment 3: Discussion

Experiment 3 used measures of eye movements during reading to investigate the influence of connectives in aiding negation processing. The results provide evidence for a facilitatory effect of connectives in discourse processing. These results were consistent with findings that connectives provide a benefit to reading as they provide readers explicitly with the coherence relation between two pieces of linguistic information. Without the connective, readers would have had to infer the relation between text segments, a more cognitively demanding process (Kuperberg, Paczynski & Ditman, 2011; Traxler, et al., 1997). Instead, the relationship between sentences was explicitly denoted to the reader, allowing them to constrain their expectations of upcoming text. The facilitation of negation processing, however, was modulated by the boundedness of a negated element. Target word analyses produced evidence that connectives facilitated early measures of bounded negation processing in the complementary condition, and later measures in the unbounded complementary condition. Post-target word analyses suggested late facilitation of the unbounded incongruent condition. Finally, no facilitation was found for the reading of the bounded incongruent condition.

In the bounded complementary condition, it was predicted that the presence of a connective would provide very early facilitation to processing. The interpretation of bounded negation is considered to occur very rapidly, due to its lack of ambiguity, and easily integrated with its antonym (Anderson et al., 2011; Du et al., 2014; Paradis & Willners, 2006; see Chapter 2). Any integrative facilitation from the presence of a connective, therefore, could occur very rapidly. This rapid facilitation was evidenced by shorter first fixation and gaze durations on the target word. During first pass reading, the connective facilitates integration of the bounded negation (*not dead*) with its antonym (*alive*). Rapid integration of bounded complementary passages can be easily incorporated with our knowledge of boundedness, specifically, the notion that a bounded negations' similarity to its antonym allows for rapid integration of that negation.

Next, consider the unbounded complementary condition, where it was predicted that any facilitation provided by the presence of a connective would occur within a slower time course. The interpretation of unbounded negation is considered to occur within a less rapid time course compared to bounded negation, due to its

ambiguity, and readers struggle to integrate unbounded negation with its antonym (Anderson, et al., 2011; Du et al., 2014; Paradis & Willners, 2006; see Chapter 2). It was found that the integrative facilitation supplied by the connective was delayed slightly, still occurring during first pass reading, but in 'later' measures of processing. Instead, facilitation was found in faster go-past reading times on the target and decreased first pass regressions out of the target. Readers were less likely to make a regressive eye movement, resulting in less re-reading of previous content and thus participants moved past the target word faster. No benefit, however, was provided to first fixation or gaze duration. The integrative facilitation of the connective, therefore, produced a delayed effect in reading of the target. This suggests that readers could not use the connective to facilitate integration of the unbounded negation (*not early*) with its antonym (*late*) until the unbounded negation had been fully represented into discourse. Even though the connective has already explicitly stated the relationship between the two antonym usages, facilitation is delayed until a meaningful representation of the unbounded negation has been computed. As a result, a delayed effect of facilitation was observed. To be clear, there appears to be a delay in the representation of unbounded negation, due to its ambiguity. The connective appeared to cause facilitation of later integrative processing, rather than the initial representation of the negated antonym.

The results of Experiment 3 are consistent with previous processing models of negation. Dynamic Pragmatic theories of negation have detailed the multitude of pragmatic variables can be taken into account in order for readers to comprehend negation incrementally (Giora, 2006; Tian et al., 2010; 2016). One such variable being the specificity of a representation the negation provides (Anderson et al., 2012; Du et al., 2014; Paradis & Willners, 2006). Ambiguous negation, i.e. those that suggest multiple alternative states, are instantiated more slowly (as is the case with unbounded negation), compared to unambiguous negation, i.e. those that suggest only one alternative, which is instantiated into discourse very rapidly. It has been established that connectives are incorporated into incremental interpretation, with readers able to use the coherence relation information to facilitate semantic integration processing. The results of Experiment 3 are interpreted here, as being due to the fact that facilitation cannot occur until the negated representation has been fully instantiated into a discourse representation.

For instance, *not dead* can be represented rapidly as a representation of *alive,* as it was the only alternative available from that negation. Subsequently, very early facilitation of integrating these two representations was found. Immediate integration was possible in the bounded case because the negation was quickly represented, allowing for semantic integration of these two states into a unified representation to begin earlier. The connective could, therefore, very quickly facilitate integration of the complementary negation with previous discourse (i.e. that *not dead was* synonymous with the previously stated *alive*). As unbounded negation was more slowly processed, due to its ambiguity, the integrative facilitation of the connective occurred within a slower timecourse. The differential pattern of facilitation provides evidence to support the general facilitative role of connectives in integrating text with previous discourse. It was, however, a process modulated by the speed at which text can be meaningfully represented. Unlike in the bounded case, where the negation can be represented rapidly, unbounded negation is ambiguous, and represented into discourse more slowly. It could be suggested that it is the ambiguity of unbounded negation that delayed any facilitative effect of the connective in the unbounded complementary condition, as the connective was not facilitating representation of the unbounded connective as such. The results provide general support for the notion that connectives facilitate integrative processing (Murray, 1995; 1997; Traxler et al., 1997ab)). To be clear, integrative processing refers to the interaction of multiple elements within a discourse representation. Integration allows for the construction of a parsimonious understanding of the text and the relationship between multiple text units.

A lack of facilitation of processing bounded incongruent negation was found within Experiment 3, beyond a main effect of faster reading in the passages of text with connectives present, compared to absent. This extends the findings of Experiment 2 in showing that readers are sensitive to the boundedness of negated elements. Bounded states are mutually exhaustive of each other. Someone cannot be, under reasonable circumstance, both *dead* and *alive*. Even with a connective to indicate that two states will not match, readers were severely disrupted in integrating a discourse model featuring two bounded negations. Readers displayed disrupted reading patterns during the reading of incongruent passages, even when a connective constrains a reader to expect some degree of contradiction. The fact that the bounded

incongruent passages feature no cue to suggest there is an alternative to the logical contradiction presented could also explain why no facilitation was found from the presentation of a connective. As previously stated, a connective facilitates processing by allowing readers to integrate multiple representations together. Readers constrain their expectations accordingly, allowing for facilitatory processing of text when these expectations are met. This integrative facilitation, however, cannot occur when readers are simply unable to interpret the negation in non-anomalous manner. If the bounded concepts were both clearly shown to be subjective, for instance, this would remove the flat contradiction, and present the text as a differing of opinion/someone being misinformed (see further research below). It could be the case that situations such as these would allow readers to process the text without detecting an anomaly, and allow for the use of the connective during integrative processing.

Furthermore, the level of inferential processing required in disambiguating a third state in between two unbounded incongruent negations led to little facilitation when a connective was present. It should be noted that the incongruent conditions were the only condition to feature an adversative connective, which is widely accepted as being more cognitively demanding (Xu, Chen, Panther & Wu, 2017). This is because they denote a contrast, which features two separate representations. The relation denoted by adversative connectives is also considered more complex relation than causal connectives, as in the latter case the two representations can be integrated under a common theme (Knoepke et al., 2017). Furthermore, adversative connectives explicitly deviate from the expected temporal order of text, as mentioned during the discussion of Murray's (1996; 1998) findings. No facilitation was found in the unbounded incongruent condition. This can be explained by the fact that unbounded incongruent passages have a conciliatory representation (e.g. *not late* and *not early* = *on time*) that involves a great degree of inferential processing, in order to be reached. The results of Experiment 3 suggest this is a time-consuming process, as there is no facilitation from the presence of a connective in the unbounded incongruent condition. The level of referential processing required within unbounded incongruent negations, therefore, severely disrupts processing, leading to a very delayed timecourse.

The findings of Experiment 3 extend our understanding of the role of connectives in discourse comprehension. There are many previous studies that

provide evidence showing that the use of a connective can provide an immediate facilitation to sentence processing (Kohne & Demberg, 2012; Traxler et al., 1997; Xu et al., 2017). As Experiment 3 evidenced facilitation to processing from the target word onwards (in essentially every measure on every region), further suggesting that readers can use connectives effectively during on-line text comprehension. Connectives establish the relationship between separate text units, allowing readers to constrain their expectations of upcoming text. Furthermore, these expectations are based on the connective and its relationship to previous text.

Further research should investigate the effect of epistemic markers on the incremental interpretation of bounded and unbounded scenarios. For instance, previous studies have shown that subjective and diagnostic states are slower to instantiate as they require the creation of a "mental space" for them to occur within (Traxler et al., 1997). This delay, however, has been alleviated by the presence of epistemic markers (Canestrelli et al., 2013). From the results of this experiment (and others, Traxler et al., 1997), a theoretical motivated hypothesis is that that the use of epistemic markers (e.g. *the Doctor thought … the Nurse thought)* could alleviate any delays in reading found in Experiments 2 and 3, as any disagreement would be understood as being due to a difference of subjective opinion. Furthermore, bounded sentences should still be resistant to this effect as they are less based on opinion and more on categorical fact (e.g. *the patient is dead, the door was open, he is asleep)* (Warren, 1992). Furthermore, if one were to take a population who have been characterized as excelling in basic linguistic processes (Minshew, Goldstein & Siegal, 1995), but have problems in the creation of "mental spaces" (Fauconnier, 1985); such as false belief tasks (Baron-Cohen, Leslie & Frith, 1985; Frith, 2003) theory of mind functioning (Melzoff & Gopnik, 1993; Baron-Cohen, 2000) or counter-factual reasoning: (Hadwin, Baron-Cohen, Howlin & Hill 1997, Scott, Baron-Cohen & Leslie, 1999), such as those with autism spectrum disorders, one would still observe an effect of boundedness regardless of the epistemic markers (i.e. even in the unbounded case).

In conclusion, from Experiment 3, evidence has been provided that speaks to two issues within psycholinguistics: the informative power of connectives and negation processing. Connectives provided a general facilitation to the reading of sentences within which they appeared. Connectives did, generally, facilitate reading,

as they provide readers explicitly with the coherence relation between two separate units of text. The level and time course of this facilitation was, however, modulated by the boundedness of negated elements also present within the connected sentence. Early measures of processing showed facilitatory effects for bounded complementary negations separated by a connective, compared to later measures of processing in the case of unbounded complementary negations. These results have been interpreted as displaying a delay in the representation of unbounded negation, and a lack of constraint is provided by unbounded negation, due to its ambiguity. In comparison, bounded negation is categorical, and processed within an earlier time course. Connectives facilitated the reading of complementary negation. Facilitation was immediate in the case of bounded negation, but delayed when processing unbounded negation.

Chapter 5

An Eye Movement Investigation into the Default Interpretations of Negated Terms

Across Experiments 1-3, it has been displayed that language processing includes some sensitivity to the linguistic operator of boundedness. Readers have been shown to be sensitive to a boundedness manipulation when making offline similarity judgments based on their ultimate interpretation of text (Experiments 1b, c). This sensitivity has also been evidenced using eye movement measures to assess on-line processing of written language (Experiment 2). Furthermore, it appears the time course of integrating bounded and unbounded negation is affected by the presence of a connective (Experiment 3). The interpretation for these results within this thesis is built on the notion that unbounded negation does not denote a categorical state in the way that bounded negation does (*not dead* is considered similar to *alive* whereas *not late* is not interpreted as *early*). As bounded states are said to be mutually exclusive, due to the presence of only two states within a bounded concept, bounded negation very clearly denotes a single state. In contrast, unbounded concepts can denote multiple states. As a result, there is an inherent ambiguity associated with the interpretation of unbounded negation.

From the suggestion of an ontological difference between bounded and unbounded concepts, it is possible to provide representational accounts for the findings of Experiments 2 and 3. Readers suffer reading difficulty comprehending two bounded negations (compared to a complementary bounded negation), as they cannot integrate the two states (one cannot integrate *not dead* with *not alive*). The two states are unambiguous, mutually exclusive and exhaustive. While the use of a connective can have an initial facilitatory influence on bounded complementary negation, it still cannot prevent readers from suffering the disruption associated with bounded incongruent negation, due to the logical contradiction present. Unbounded negation, in contrast, does not necessarily denote an explicit state. As a result, there is a level level of inferential processing required in the case of both unbounded incongruent and complementary negations. Readers require inferential processing to

disambiguate and instantiate a possible, conciliatory representation. Furthermore, for unbounded negation, there is a less immediate facilitatory effect when a connective is provided. As unbounded conflicting negations require a level of inferential processing, it would appear these computations delay the integrative facilitation of the connective.

A further research question, however, remains – how do readers overcome the ambiguity of unbounded negation? It is logical that two possibilities exist. Readers either overcome the ambiguity of the negation by creating an underspecified representation, or by representing a/multiple midpoint/s as a default. Chapter 5 explores these two possibilities, reviewing previous literature on how readers represent underspecified language. An eye movement experiment is then presented, which investigates how readers represent unbounded negation.

Introduction

There has been general agreement that the Gricean maxim of quantity is an important tenet for successful communication. That is specifically that communicators, in general, try and be as informative as possible. There is, however, a growing area of investigation into occurrences where there are multiple/ambiguous interpretations to be drawn from language.

Ambiguity Resolution in the Study of Perfectivity

While discussed extensively throughout this thesis, the ambiguity denoted by unbounded negation is not a unique phenomenon within language. Verbal aspect has also been shown to be a grammatical variable that affects the specificity of a representation denoted within discourse. Verbal aspect is a variable that indicates an events' duration and completion status (Comrie, 1976) and has been categorized into perfective and imperfective states (Dowty, 1986). Perfective statements refer to those that are complete (e.g. *the boy walked to the shop*), whereas imperfective statements are those that are presented as being in progress (e.g. *the boy was walking to the shop*). Madden and Zwaan (2003) investigated whether readers were sensitive to this

categorization of aspect during language comprehension. They argued the aspect used to present information would have a direct effect on the internal structure of subsequent discourse representations. Perfective representations should unambiguously and categorically denote the completed event. So, for example, in the previous example, the representation will be of a *boy* at the *shops*. In contrast, imperfective representations need to include the various stages of completion of a task. In order to capture the possible number of states that could be denoted by this statement, readers would need to represent many stages of the *boy* going from one location, to the *shops*. It is in this manner that imperfective statements require some form of ambiguity resolution in order to be specifically represented.

Madden and Zwaan's (2003) sentence-picture verification task required participants to read perfective or imperfective sentences and then indicate whether the picture they were presented with matched the statement or not. The pictures were either of completed events or events that were in progress. They found judgments for perfective statements were made faster when presented with a picture of a completed event, compared to an in progress event. Conversely, no difference of reaction times was found between the two picture types for judgments on imperfective statements. This provided evidence that readers were sensitive to manipulations of verbal aspect when processing language. When presented with perfective statements, there was facilitation in recognizing completed events, whereas no facilitation was found for either completed or in progress events having read an imperfective statement. The authors suggested in their study that readers must generate multiple stages of completion when representing imperfective statements. It is in this way that they argued readers overcome the ambiguity inherent within an imperfective statement. In contrast, perfective states are definitive about the state denoted, imposing greater constraint upon the representation readers will instantiate. There are clear similarities here with boundedness, where bounded events provide greater constraint on the discourse representations of readers than unbounded events. Of course, while communicators are motivated to be informative (Grice, 1975), ambiguity in language remains pervasive. In order to process such ambiguities, readers must have processing strategies in place to overcome such uncertainty.

Attempts to explain how this ambiguity resolution is overcome have suggested that readers focus on different semantic features when interpreting imperfective events. When communicating in the perfective case, it has been suggested the communicator wishes to focus on results (in other words, the goal of the action) the completed action. In contrast, when communicating using imperfective verbs, it has been suggested readers wish to focus on the ongoing event itself (or the source of the action – Truit & Zwaan, 1997). Ferretti, Rohde, Kehler and Crutchley (2009) suggested that readers interpret more on the 'source' rather than the 'goal' when processing imperfective statements compared to perfective statements. Their sentence completion data showed that readers focus the content of their completions more on *Mary* than *John* in sentence 1, if it was presented in the perfective aspect, compared to imperfective aspect. The argument offered here was that as imperfective states are incomplete, readers focus more on the action rather than the goal state, with the opposite true in the case of perfective statements. The authors suggested the nature of verbs used during communication would constrain expectations of upcoming text. If one uses an imperfective verb, for instance, it would be logical that they wish to focus on the action itself. In contrast, when using a perfective statement, where the event is finished, readers appear to wish to focus on the goal of that finished action. These results suggest when readers wish to talk about goal or source information; they will be biased as to whether they use perfective and imperfective verbs.

1. perfective/imperfective - *John handed/was handing a book to Mary.*
2. perfective/imperfective - *He pounded/was pounding the nail.*

Furthermore, Truitt and Zwaan (1997) found the word *hammer* was responded to more quickly in a lexical decision task when sentence 2 was presented in the imperfective aspect. Once again, readers focus more on the source of the action (*the hammer*) rather than the goal state in the imperfective case. Ferretti, Kutas and McRae (2007) found readers indexed location information more strongly for imperfective statements than perfective statements. In a word naming task, participants were quicker to read location words that were typical of the situation they had just read, but only when presented in the imperfective aspect. For example, participants were quicker to name *kitchen* than *gymnasium* in the context of someone

cooking but not having *cooked*. Finally, Sherrill, Eerland, Zwaan and Magliano (2015) presented evidence that participants interpreted more intention on the part of actors in imperfective statements than perfective statements. Specifically, they presented participants with a vignette where someone was *punching* someone else, they were more likely to judge that person as guilty of first-degree murder (as opposed to second-degree where intention is taken away from the defendant) than if they were described as having *punched* someone. In sum, from these experiments, the view was taken that, in order to overcome the ambiguity present within imperfective statements, readers focus on different details in representing that information. Areas of focus include locational, source and intentionality information. Communicators are sensitive to the perfectivity of verbs, and subsequently adapt their expectations of text based on this information. As imperfective statements are not finished, communicators use this aspect to communicate information about the source of the action. As perfective statements are finished, communicators use this aspect to communicate information about the goal of the action.

While these investigations enlighten us as to the effects of focus upon the reading of imperfective and perfective statements, they do not provide us with an account of the nature of an imperfective representation when attempting to accommodate its inherent ambiguity into their understanding of discourse. The explanations suggest that readers constrain their expectations of text according to aspect (Ferretti et al., 2009). Madden and Zwaan (2003) suggest that in order to accommodate the inherent ambiguity within imperfective statements, readers represent the event at multiple stages of completion, in order to capture the "in-progress" nature of the event. Perfective events, in contrast, are represented with a single, definitive representation of the event. As a result, the representation of imperfective events is predicted to be slower than perfective events, due to the increased number of representations. As previously discussed, however, the evidence provided for this account is the fact that perfective events prime recognition of picture probes of completed events, compared to incomplete events, whereas imperfective prime neither.

In contrast to this account, Zhou, Crain and Zhan (2014) found no delay in the understanding of imperfective information. They used the visual world paradigm to

investigate whether readers were encoding aspectual information on-line during language comprehension. They found readers would immediately move their eyes to the appropriate picture, either an action in progress or a completed action, upon hearing the perfective or imperfective verb. Aspectual sensitivity was found in adults and 5 year olds in Mandarin, suggesting language learners learn to use aspectual information very early in development, in order to shape their incremental interpretation of text and place constraints on their expectations of incoming text. The ambiguity of imperfective statements did not lead to a delay in processing; suggesting readers are well equipped to handle these events in language. Similarly, contrary to offline evidence, no delay was found in the detection of a semantic incongruity in the reading of unbounded negation in Experiment 2. If readers are processing these negations by instantiating multiple possible representations, it does not appear to cause a delay in on-line language comprehension.

Underspecification in Language Processing

An alternative hypothesis, however, is that, when faced with multiple possibilities, readers underspecify their representation. Effectively, once a word has been lexically accessed, readers could instantiate a representation that is not semantically detailed (Frisson, 2009). In this way, readers could await information that will disambiguate how they should construct their situational model. This hypothesis was also provided by Pickering, McElree, Frisson, Chen and Traxler (2006), who argued that when presented with an ambiguity, readers do no commit to a specific representation of that ambiguity until discourse makes it imperative to do so (in terms of correctly understanding the linguistic information being presented).

Support for an underspecification hypothesis is provided by Pickering et al.'s (2006) manipulation of aspect. As opposed to the studies above, they manipulated the perceived length of events (also known as telicity), rather than the tense/completion status of an event. For instance, the verb *hopped*, is considered a bounded, telic event, because it has a very short duration that has a very obvious end point (when the actor hopping reaches the ground). In contrast, verbs such as *glided* are said to be unbounded, atelic events as they possess a longer (potentially endless) duration. As

such, it has been posited that atelic events must be either be instantiated with multiple representations or underspecified.

The motivation for Pickering et al's (2006) study followed from research conducted by Pinago, Zurif and Jackendoff (1999) who provided initial evidence to suggest readers do not underspecify their representation when interpreting telic and atelic events. Their results indicated that interpreting the bounded event in sentence 3 was more costly than interpreting the unbounded event in sentence 4. They argued that while sentence 3 is perfectly possible, it involves manipulating a bounded event (a *hop*) to be unbounded (the event of continuous *hopping*), and this semantic reanalysis causes processing delays. Pinago et al.'s experimental evidence for this conclusion came in the form of lexical decision task data, in which the items were unrelated words presented while listening to sentences such as 3 and 4. They found longer naming latencies when listening to sentence 3, compared to sentence 4. They argued this difference was due to the increased level of inferential processing in sentence 3, where upon reaching the word *until*, readers have to "coerce" the bounded event to be unbounded. To be clear, in this case, readers must take a single, telic event of one *hop* and coerce that representation to an atelic series of *hops*. While, the sentence *the insect hopped effortlessly* is a bounded event, the series of hops in sentence 3 are not, meaning readers must attempt to adjust their representation of the *hop*, leading to processing delays.

3. *The insect hopped effortlessly until it reached the garden.*
4. *The insect glided effortlessly until it reached the garden.*

In contrast, Pickering et al. (2006) argued that sentence-processing mechanisms are much more likely to underspecify in these sorts of cases, in order to avoid suffering any processing difficulty such as this. They argued task effects influenced effects of coercion, such as those seen in Pinago et al. The inclusion of a lexical decision task means processing in this situation is not directly comparable to natural language comprehension during reading. Furthermore, Pickering et al. found no disruption to reading when participants read sentences that featured a telic entity within an atelic context (such as sentence 3), using self-paced reading times and eye movement measures in two separate experiments. They argued that readers are not

sensitive to this sort of coercion manipulation during on-line processing of text. Instead, readers underspecify the telicity of their representation, unless forced to make a commitment. If processing of boundedness is similar to that of telicity and aspect, therefore, it could be suggested than in the case of unbounded negation, which is inherently ambiguous, readers choose to overcome this ambiguity, by underspecifying their representation.

Pickering et al. also argue that underspecification is quite pervasive within language and not just within the processing of telicity. For example, Frazier and Rayner (1990) argued for 'minimal commitment' during language comprehension, such that, in the event of a text level ambiguity, readers will not commit to a specific interpretation of text until necessary, in order to avoid misanalysis of text. They provided evidence in an experiment where readers encountered words that had one meaning, but could refer to multiple senses (polysemous words). For instance, *newspaper* could refer to the object or the organization. These polysemous words were embedded within a context that did not disambiguate which meaning was intended until after the word appeared. For example, in sentence 5a, it refers to the concrete noun, whereas 5b refers to the more abstract organizational noun.

5a. *Unfortunately the newspaper was destroyed, lying in the rain.*

5b. *Unfortunately the newspaper was destroyed, managing advertising so poorly.*

6a. *Yesterday her date surprised Jane, by tasting so bitter.*

6b. *Yesterday her date surprised Jane, by walking in so late.*

They found that there was no delay in fixation times in these cases, compared to sentences that presented homonymous words (lexical items that have multiple meanings) within contexts that were shown to be incorrect (such as sentence 6a where the subordinate meaning of *date* is used, compared to dominant to 6b). In the case of sentence 6, readers commit to the dominant meaning of the lexical item. In contrast, in the case of sentence 5, where the words have the same meaning but can refer to multiple senses, it would appear that readers do not commit when the sense of the word has been left ambiguous. Frazier and Rayner (1990), therefore, argued that readers do not commit to a specific representation until forced to do so, suggesting that when readers encounter words of ambiguous meaning, readers

underspecify until necessary. Within their theory of minimal commitment, it was suggested that while readers incrementally interpret text, there are limits on this system, particularly when faced with ambiguities. In these cases, readers do not commit to a representation unless incompatible choices are presented, or readers need to maintain consistency within the text.

Further support for readers frequently underspecifying their representations of discourse came from Frisson and Pickering (2000). They found that readers did not commit to ambiguous verb meanings when it was not necessary. This was evidenced by a lack of reading delays for sentences that used the subordinate meaning of *disarm* (remove hostility) compared to sentences that used the dominant meaning (to remove a weapon). To be specific, in sentence 7, it can be seen how the meaning of *disarm* is not made unambiguous until after its use (specifically, at the word: *critic*). If readers immediately committed to a representation of the dominant meaning, therefore, they would have experienced reading delays when the meaning was shown to be of the subordinate. As there were no differences in comparison with sentences that use the dominant and subordinate meaning (sentences 8 and 7 respectively), they concluded readers did not commit to a specific representation.

7. *Mr. Graham is quite certain that they disarmed almost every critic who was opposed to spending more money on art.*

8. *Mr. Graham is quite certain that they disarmed almost every rebel and sent them to prison for a very long time.*

Furthermore, theories of underspecification fit well into "good enough" theories of language processing. "Good enough" theories argue that within many language comprehension contexts, semantic processing of text is not always completely defined, leading to only partial representations of language being formed by readers (Ferreira, Bailey & Ferrero, 2002). This is supported by evidence showing that when presented with garden path sentences, whereby a readers' initial syntactic parsing of a sentence is incorrect; the reader will often maintain the incorrect parse of the text even at syntactic disambiguation. Despite disruption to reading in garden path sentences (Frazier & Rayner, 1982), indicating readers detected their initial

misanalysis; it has been shown that readers do not always correct their initial interpretation to the correct one. Christianson, Hollingworth, Halliwell, and Ferreira (2001) had participants read garden path sentences such as 9, but also asked questions directly related to the syntactic ambiguity present within the sentence.

9. *While Bill hunted the deer ran into the woods.*

10. *The deer ran into the woods while Bill hunted.*

Question: *Did Bill hunt the deer?*

Typically, participants spent longer fixating the word *ran*, as it was at this point that it was disambiguated that *the deer* was actually the main object of the clause, and not a direct object of the verb *hunt*, which is the initial parsing participants usually take during the reading of this sentence. Despite this, Christianson et al. still found participants were more likely to answer "yes" in the case of sentence 9, compared to sentence 10, where no garden-path is present. They argued this is due to a "lingering misanalysis" of the temporary ambiguity. Furthermore, if readers were always instantiating fully defined representations of language, this misanalysis would not be allowed to "linger". This presents a context within which participants do not choose to completely define their representation of linguistic meaning during reading.

These effects have been replicated using eye tracking (Slattery, Sturt, Christianson, Yoshida & Ferreira, 2013) and in children (Wonnacott, Joseph, Adelman & Nation, 2016), showing a prevalence of this phenomenon within language comprehension. Another scenario concerned cases where readers often failed to detect local anomalies present within utterances, such as when reading the question *Where should we bury the survivors* (Barton & Sanford, 1993). If readers were activating fully defined semantic representations when reading this sentence, anomaly detection should have certainly been present. Readers, however, often did not detect any anomaly when reading such sentences. Barton and Sanford suggested that instead of fully defined understanding of text, readers often attempt to "establish coherence". That is to say, as long as text is coherent, readers will not detect an anomaly, as coherence requires a lack of logical or semantic contradiction. In this context, *survivors*, *crash* and *airplanes* are all constituent parts of a schema associated

with air disasters. It was possible, therefore, to establish the coherence *burying survivors* in this context, without immediately detectable as an anomaly. It would appear readers often undertake rather shallow processing of lexical-semantic information.

The commonality across these findings has been the suggestion within certain contexts, readers do not necessarily instantiate a fully defined representation,, especially when it is not required to maintain coherence. Underspecification, therefore, could be a viable theoretical explanation for cases like these where readers do not duly commit to a representation during incremental interpretation.

Experiment 4: How do Readers Accommodate the Ambiguity of Unbounded Negation during Language Comprehension?

The aim of Experiment 4, therefore, was to investigate how readers interpret the ambiguity that is communicated within unbounded negation. Across Experiments 1-3, it has been repeatedly shown that readers are sensitive to the ambiguity within unbounded negation during language comprehension, in offline and on-line measures. One limitation that remains, however, is a lack of experimental evidence for how exactly readers are interpreting unbounded negation. In this Introduction, two relevant potential theories have been posited: 1) it is possible that readers overcome the ambiguity present within unbounded negation by instantiating a midpoint representation (i.e. representing *on time* for *not early*), as has been suggested by Madden and Zwaan (2003) when processing imperfective events; 2) it is possible that readers overcome the ambiguity of unbounded negation by underspecifying the representation. To explore which of these theories might hold true, in Experiment 4 of this thesis, a further manipulation of the complementary condition was conducted, in order to elucidate how readers assimilate the ambiguity of unbounded negation into their discourse representation.

In Experiment 4, the passages of Experiments 1c, 2 and 3 were taken, and a new condition was introduced in place of the contradictory condition, called the affirmative complementary condition. The repetition and (negated) complementary conditions were still used in Experiment 4 (see Table 5.1 for examples of all

conditions in Experiment 4). To be clear, in this experiment the negated repetition condition, the same antonym was repeated twice in its negated form (e.g. *not alive – not alive*). The negated complementary condition featured different antonyms, with only the second negated (as in Experiments 2 and 3, e.g. *alive – not dead)*. In the affirmative complementary condition, antonym usages are reversed from the negated complementary condition. The first antonym usage, therefore, was negated, followed by a different antonym in the second usage, presented in the affirmative form (e.g. *not dead – alive*). Experiment 4, therefore, investigated how readers would interpret these kinds of passages. It was predicted that there would relatively little delay in the reading of bounded affirmative complementary passages. Readers would still need to reference the previous negated bounded state, but as the negation matches the affirmative antonym, readers should suffer very little disruption during this referential processing.

There are, however, two potential predictions in the case of unbounded affirmative complementary passages. If it were the case that readers instantiate multiple representations into discourse when they encounter ambiguous text, as suggested by Madden and Zwaan (2003), then processing delays in the reading of the unbounded affirmative complementary passages would be expected, relative to the bounded equivalent. This would presumably reflect similar ambiguity resolution to that found in the unbounded complementary condition. In this case, when readers encounter the negation (*not early*), they would instantiate a midpoint representation, or multiple representations. When this was shown to not match the second antonym usage (*late*) readers would suffer disruption to reading due to their misanalysis of the text. To be clear, if readers are committing to a midpoint representation (*on time*), this is clearly not equivalent to the second antonym, which is a polar state (*late*), requiring readers to update and revise their interpretation. Thus, delays from the target word onwards would be predicted in this condition, when compared with the repetition conditions, which would be comparable to those seen in the unbounded complementary condition.

Table 5.1. Regions of interest in the (i) bounded repetition, negated complementary, affirmative complementary and (ii) unbounded repetition, negated complementary and affirmative complementary passages.

Region of Interest	Text
(i) Licensing Context	Rushing into the emergency room, the doctor and the nurse were talking about one of their cases.
First Antonym Use	|The doctor stated clearly that the patient was| (not) | **alive**. |
Repetition Sentence	| The nurse declared that the patient was | not | **alive |** and noted it down in her paperwork. |
Negated Complementary Sentence	|The nurse declared that the patient was | not | **dead**| and noted it down in her paperwork. |
Affirmative Complementary Condition	|The nurse declared that the patient was | **dead**| and noted it down in her paperwork. |
Wrap-Up Sentence	| Great care was taken to regularly check the condition of all the patients. |
(ii) Licensing Context	The boss was checking his new employee's attendance record with his secretary.
First Antonym Use	The boss was quite sure the employee was (not) **early**.
Repetition Sentence	Following her orders, the secretary noted in her records that the employee was | not | **early** | for work today. |
Negated Complementary Sentence	Following her orders, the secretary noted in her records that the employee was | not | **late** | for work today. |
Affirmative Complementary Sentence	Following her orders, the secretary noted in her records that the employee was | **late** | for work today. |
Wrap-Up Sentence	| It was the secretary's job to maintain employee records. |

In contrast, if readers choose to underspecify their representation, not committing to a specific representation when they encounter ambiguous negation, we would not predict these delays in the reading of unbounded affirmative complementary passages. This underspecification hypothesis, motivated by the accounts of Frazier and Rayner (1990) and Pickering et al. (2006) suggests readers do not commit to a specific representation of ambiguous terms, unless they are forced to by the context. Instead, rather shallow lexical-semantic processing occurs, where they leave their interpretation of text underspecified, in order to integrate the ambiguity efficiently. In the case of unbounded affirmative complementary passages, therefore, we would predict very little disruption to reading. When readers fixated the first negation (*not early*), they would underspecify their representation, thus not making a semantic commitment. When they reached the affirmative antonym (*early*), readers would be presented with disambiguation of the previous negation, thus this could be readily integrated into discourse. It is feasible that this processing would be comparable to the bounded case, and no more time-consuming than the processing of negated complementary passages.

The aim of Experiment 4, therefore, was to investigate how readers interpret the ambiguity that is communicated within unbounded negation. The antonym orders of the bounded and unbounded passages were manipulated in order to test two theories of how readers interpret ambiguous text. The first, suggests multiple representations of a midpoint are represented, while the second suggests readers underspecify and do not commit to a specific representation. The eye movement data from Experiment 4 will elucidate which of these is the case in the representation of unbounded negation.

Experiment 4: Methodology

Participants

Forty participants (34 females) with a mean age of 20 (range 18-36) were recruited from the University of Southampton and took part for course credit or a small cash payment (£6/hour). All participants were native English speakers and reported normal or corrected to normal vision.

Materials and Design

A within-participants 2 x 4 design was used, with the factors of boundedness (bounded, unbounded) and passage type (repetition-affirmative, repetition-negated, complementary-affirmative and complementary-negated). As in Experiment 3, the variable of markedness was not considered and, instead, polarity was counterbalanced across items. The material passages were those from Experiment 2, with differing antonym and negation orderings as discussed above (see Table 5.1). Regions of interest can also be seen in Table 5.1.

Procedure

Procedure was the same as used in Experiment 2.

Experiment 4: Results

Data exclusions matched those used in Experiment 2. These exclusions accounted for 4.93% of the data. Prior to data analysis, data for each eye movement measure that were more than 2.5 standard deviations from the condition mean for each participant were removed (affecting <1% of dataset). Data loss affected all conditions similarly (i.e. no differences across conditions, all $ts<1$). Across participants, 84% of the comprehension questions were answered correctly with no differences observed across conditions (all $ts<1$).

Analyses

Data analyses and design of LMEs were the same as in Experiment 2, but with the contradictory level of passage type replaced with the affirmative complementary conditions. To reiterate, boundedness was only inserted into the models as an

interaction term for early measures on the target region, with successive difference contrasts between conditions were run when a significant interaction was found. In the interaction analysis, as successive difference contrasts were used for the fixed factors, the intercept corresponds to the grand mean and the fixed factor estimate for a categorical factor can be interpreted as the difference between the two conditions. These analyses are summarized in Table 5.4. The means and standard deviations of all six measures across all eight regions can be found in Tables 5.2 and 5.3.

Regions and Measures

Five measures of reading were analysed across eight regions of interest (see Table 5.1). The measures and regions of interest were identical to those in Experiment 2. See Tables 5.4-6 for the LME analyses of these measures.

First Pass Measures on the Target Region

As in Experiment 2, only first pass measures on the target region were analysed with an interaction between passage type and boundedness. For first fixation duration, there was a main effect of passage type, such that affirmative complementary target words received longer first fixations than repetition and negated complementary target words (which did not differ from each other). For gaze duration, there was a main effect of passage type, such that affirmative complementary passages received longer first pass fixations on the target that repetition passages. The negated complementary condition did not differ from either the affirmative complementary condition or the repetition condition. For regressions out of the target word, there was no main effect of passage type. There was no significant interaction of boundedness and passage type for the measures of first fixation duration, gaze duration or regressions out of the target word.

Readers did not show sensitivity to the variable of boundedness prior to a saccade to leave the target word, resulting in a lack of significant interaction between passage type and boundedness. These results suggested readers processed the affirmative complementary target word in a similar manner, regardless of whether the target word was bounded or unbounded. Specifically, readers appeared to show an immediate detection of the need to refer the target antonym back to the previous negation, evidenced by longer first fixations, compared to the negated

complementary and repetition conditions. The lack of interaction suggested a general processing strategy when negation was presented without disambiguation, regardless of boundedness. Readers regressed back into the text more in the negated complementary case, compared to the affirmative complementary condition. Representing a qualitative difference in the oculomotor behaviour of readers for these two types of passage, suggesting a difference in the difficulty of integrating a negated item with its antonym.

Bounded Analyses

Analyses for Later Measures of Target Region

All subsequent analyses pertained to models that did not include boundedness as an interaction term, as they included fixations on regions of text that were not comparable across boundedness due to content differences. In terms of later measures for the target region, it was found that both the bounded complementary condition yielded longer go-past reading times and total reading times than the repetition condition. The affirmative and negative complementary conditions did not differ from each other for either measure. Given that the negated complementary condition yielded more regressions out of this region, it is unsurprising that this condition also yielded longer go-past times. This also suggests increased total reading times were attributable to longer second pass reading times, following regressions back into the text, given there were no increases in first pass reading times. In the affirmative complementary condition, longer first pass durations were attributable to both effects. That is to say, longer first pass fixations on the target word resulted in longer total reading times, both relative to the repetition condition. These results provided evidence to suggest that both bounded complementary conditions resulted in disruptive reading patterns on the target word, both of which can be attributable to longer first pass reading/more first pass regressions from the target word.

Post Target Region

There were no significant differences of first pass reading time across the bounded dataset for the post-target region. The bounded affirmative complementary condition did, however, result in significantly more regressions out of this region than

the bounded repetition condition. The same effect was also found for go-past reading and total reading time. No differences were observed between the bounded negated complementary condition and any other condition. Readers quickly resumed a pattern of normal reading when reading negated complementary passages, replicating the results of Experiment 2. To be clear, while integrating *not dead* with *alive* did cause delays on the target word, any disruptive effects during reading were not exhibited past that region. The negation was quickly disambiguated as referring to the previously stated antonym, which was unsurprising given their semantic similarity, as found in Experiment 1b and 1c.

In comparison, readers seemed to exhibit continued disruption during reading in the bounded affirmative complementary condition into the post-target region, despite the antonym not being negated. The continued disruption was surprising, given the lack of ambiguity perceived between bounded target words and their negated antonym. It appears readers underwent some form of referential processing (i.e. referring the antonym back to a previous negation), that caused delays compared to typical reading. The reader was presumably referring the target word back to its negated antonym. While it would have been expected that readers would not suffer any difficulty relative to the negated complementary condition, the results indicated readers were suffering difficulty in referring a target word back to its antonym. Such a difficulty would only be the case if readers had not fully processed the previous negation.

Wrap Up Region

No significant differences were found in the wrap-up region for any of the bounded conditions. This suggested that readers were no longer suffering any processing difficulty within the reading of the passages by the time they fixated the wrap up region of the passage. Once again, this replicated Experiment 2; showing bounded negated complementary passages were read comparably to the repetition condition by this point. Furthermore, it suggested that by this point in the text, any referential difficulty in the reading of the bounded affirmative bounded passages had also been resolved.

Analyses of Pre-Target Regions

No significant differences were found between bounded conditions in the first region context for the measures of regressions in or total reading time. There were, however, significant effects of passage type for the measures of total reading time and regressions in the first antonym region. Readers spent longer fixating this region, in total, in both the bounded affirmative and negated complementary conditions compared to the bounded repetition conditions. The affirmative and negated bounded complementary conditions did not significantly differ from each other. There was also an effect of passage type for regressions into the second antonym, such that readers regressed into this region more in the bounded negated complementary condition, compared to the bounded repetition and affirmative complementary condition. The bounded repetition and affirmative complementary conditions did not significantly differ from each other. Both of these effects showed that, in both of the bounded complementary conditions, readers fixated the second antonym, presumably in an attempt to refer and integrate its meaning with the target antonym. There was no effect of passage type on total reading time for the second sentence context in the bounded dataset. Readers did, however, regress into this region more in the bounded negated complementary condition, compared to the bounded repetition and affirmative complementary condition. The bounded repetition and affirmative complementary conditions did not significantly differ from each other. The pretarget analyses provided evidence to suggest both the affirmative and negated complementary passages caused readers to reread more of the text prior to the target region, presumably as part of the process of referring the target antonym with prior context.

Unbounded Analyses

Analyses of Later Measures for Target Region

There was an effect of passage type for go-past reading and total reading time of the target region for the unbounded dataset. Longer go-past times were exhibited for the unbounded affirmative complementary condition compared to the unbounded repetition condition. The unbounded repetition and unbounded negated complementary conditions did not significantly differ for the measure of go-past time. Readers spent longer fixating the target antonym, in total, in both of the unbounded

complementary conditions compared to the repetition condition. The two complementary conditions did not significantly differ from each other.

As in Experiment 2, the negated complementary condition caused immediate disruption to reading patterns, compared to the repetition condition. It appeared that readers were immediately detecting semantic inconsistency in both of the complementary conditions. Despite the target affirmative complementary condition not featuring a negation, reading times immediately increased on the target word. Readers immediately detected the need for referential processing, in order to maintain consistency throughout the text. To be clear, it appeared that readers experienced more processing difficulty (characterized by more regressions and longer fixations) when attempting to refer an affirmative target word back to its negation, than referring a negation back to its antonym. This suggested the state of a referent had not been clearly interpreted when it had only been referred to by a negation.

Post Target Region

For the post-target region, a significant effect of passage type was found for first pass reading time, with the unbounded negated complementary condition yielding longer first pass reading time s than the affirmative complementary and repetition conditions. The unbounded affirmative complementary and repetition conditions did not significantly differ from each other. There was a significant effect of passage type for go-past reading time, regressions out and total reading time. For all three of these measures, longer reading times and more regressions were found out of both the unbounded affirmative and negated complementary conditions, compared to the repetition condition. The affirmative and negated complementary conditions did not significantly differ from one another.

The increased reading times for the negated complementary passage were also found in Experiment 2. This replication further suggested that referring an unbounded negation back to its antonym caused durable disruption. This, once again, suggested that readers underwent a level of inferential processing (i.e. instantiating a conciliatory representation of the negation that matches the previous antonym), in order to disambiguate the meaning of the second negation. The increased reading times for the affirmative complementary condition also suggested that readers

required further referential processing in order to establish a consistent representation between the two antonym usages.

Wrap Up Region

For the wrap-up region, there were no significant effects of passage type in the unbounded dataset for the measures of first pass reading time, go-past reading time, total reading time or regressions out. As in Experiment 2, readers returned to a relatively normal pattern of reading behaviour by the final sentence of the passage in all unbounded conditions. The lack of increased reading times in the wrap-up region suggests readers had largely overcome any processing difficulty before reaching the end of the passage.

Analyses of Pre-Target Regions

There were no effects of passage type for regressions into the first sentence context. Readers did, however, show longer total reading times for this region in the unbounded affirmative complementary passage compared to the repetition condition. The unbounded negated complementary passages yielded marginally significantly longer total reading times than the unbounded repetition condition. For the first antonym region, there were main effects of passage type for the measures of regressions in and total reading time. In both measures, longer reading times/more regressions in were found in the unbounded negated complementary condition compared to both the unbounded repetition and unbounded affirmative complementary conditions. Similar patterns of effects were found in these measures for the second sentence context. Clearly, in the unbounded case, only the negated complementary condition yielded a stable pattern of effects to suggest readers were rereading previous text, in an attempt to resolve the ambiguity they faced when they reached the target antonym.

Table 5.2. Mean and standard deviations for 'early' measures across all regions. (B = bounded condition. U = unbounded condition)

		First Antonym Context		First Negation		First Antonym		Second Antonym Context		Second Negation		Target Region		Post Target Region		Wrap Up Region	
		M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
First Fixation Duration	B Repetition	-	-	-	-	219	85	-	-	-	-	189	54	-	-	-	-
	B Neg Comp	-	-	-	-	220	84	-	-	-	-	198	62	-	-	-	-
	B Aff Comp	-	-	-	-	216	75	-	-	-	-	205	60	-	-	-	-
	U Repetition	-	-	-	-	208	70	-	-	-	-	185	54	-	-	-	-
	U Neg Comp	-	-	-	-	206	83	-	-	-	-	195	59	-	-	-	-
	U Aff Comp	-	-	-	-	211	81	-	-	-	-	200	56	-	-	-	-
Gaze Duration/ First Pass Reading Time	B Repetition	1306	676	248	125	237	139	716	513	225	91	209	77	515	351	1358	666
	B Neg Comp	1317	734	246	99	239	150	696	507	-	-	220	94	516	330	1352	653
	B Aff Comp	1292	732	-	-	255	162	716	510	223	108	228	105	507	347	1404	650
	U Repetition	1247	814	221	101	256	163	705	517	221	87	199	74	443	268	1469	667
	U Neg Comp	1229	688	234	141	256	163	705	581	-	-	218	89	443	301	1451	680
	U Aff Comp	1159	769	-	-	259	131	699	427	221	75	220	91	485	278	1363	699
	B Repetition	-	-	-	-	-	-	-	-	-	-	0.16	0.38	0.20	0.40	0.20	0.40

Table 5.3. Mean and standard deviations for 'late' measures across all regions. (B = bounded condition, U = unbounded condition).

		First Antonym Context		First Negation		First Antonym		Second Antonym Context		Second Negation		Target Region		Post Target Region		Wrap Up Region	
		M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Regressions In	B Repetition	0.47	0.50	0.18	0.30	0.02	0.13	0.25	0.43	0.20	0.40	-	-	-	-	-	-
	B Neg Comp	0.42	0.49	0.26	0.16	0.01	0.12	0.30	0.46	-	-	-	-	-	-	-	-
	B Aff Comp	0.48	0.50	-	-	0.08	0.08	0.16	0.37	0.24	0.43	-	-	-	-	-	-
	U Repetition	0.51	0.49	0.10	0.31	0.02	0.13	0.26	0.44	0.08	0.27	-	-	-	-	-	-
	U Neg Comp	0.47	0.48	0.06	0.24	0.02	0.15	0.31	0.46	-	-	-	-	-	-	-	-
	U Aff Comp	0.54	0.49	-	-	0.10	0.30	0.20	0.40	0.22	0.42	-	-	-	-	-	-
Go-Past Reading Time	B Repetition	-	-	-	-	-	-	-	-	-	-	242	122	640	411	1496	747
	B Neg Comp	-	-	-	-	-	-	-	-	-	-	279	144	705	420	1555	755
	B Aff Comp	-	-	-	-	-	-	-	-	-	-	275	147	669	456	1610	818
	U Repetition	-	-	-	-	-	-	-	-	-	-	241	131	591	375	1661	885
	U Neg Comp	-	-	-	-	-	-	-	-	-	-	265	139	689	460	1726	905
	U Aff Comp	-	-	-	-	-	-	-	-	-	-	258	145	741	545	1693	965
Total Reading Time	B Repetition	1528	865	322	179	209	188	840	637	276	150	243	121	573	381	1407	654
	B Neg Comp	1535	844	233	82	249	211	832	586	-	-	288	150	620	378	1428	629
	B Aff Comp	1547	846	-	-	276	232	861	608	286	168	283	139	605	395	1470	649
	U Repetition	1338	816	267	147	223	209	812		268	145	252	141	526	325	1510	668
	U Neg Comp	1439	836	300	183	254	215	836		-	-	301	198	578	392	1536	663
	U Aff Comp	1324	853	-	-	302	249	501		290	146	300	217	616	366	1502	681

Table 5.4. Fixed effect estimates from the linear mixed-effects models from bounded dataset for all measures on the target, post target and wrap up regions (FPRT – first pass reading time).

Measure	Gaze Duration/FPRT		Go-Past Reading Time		Regressions Out		Total Reading Time	
Condition	Estimate	t value	Estimate	t value	Estimate	z value	Estimate	t value
				Target Antonym				
Intercept	-	-	241.80	20.65*	-	-	241.58	20.82*
Affirmative Complementary	-	-	36.82	3.25*	-	-	44.98	3.56*
Negated Complementary	-	-	33.82	2.99*	-	-	41.84	3.32*
Contrast	-	-	-2.02	0.27	-	-	3.14	0.26
				Post-Target Region				
Intercept	515.90	13.05*	638.32	14.44*	-1.52	8.60*	578.33	12.82*
Affirmative Complementary	0.63	0.03	69.05	2.51*	0.39	2.08*	49.28	2.16*
Negated Complementary	0.65	0.03	40.54	1.47	0.20	1.05	37.57	1.66
Contrast	0.02	0.01	-28.51	1.03	-0.19	1.05	-11.71	0.51
				Wrap-Up Region				
Intercept	1367.50	17.51*	1506.80	18.55	-1.65	7.56*	1414.32	17.53*
Affirmative Complementary	-14.31	0.39	51.06	1.12	0.10	0.50	18.47	0.43
Negated Complementary	41.32	1.12	96.96	1.90	0.26	1.26	56.81	1.29
Contrast	55.63	1.51	47.78	1.04	0.16	0.86	38.35	0.80

*Note. * t>1.96. Intercept refers to Negated Repetition condition. Affirmative Complementary and Negated Complementary refer to Contrasts to Repetition Condition. Contrast refers to Comparison between Negated Complementary and Affirmative Complementary.*

Table 5.5. Fixed effect estimates from the linear mixed-effects models from unbounded dataset for all measures on the target, post target and wrap up regions .

Measure	Gaze Duration/FPRT		Go-Past Reading Time		Regressions Out		Total Reading Time	
Condition	Estimate	t value	Estimate	t value	Estimate	z value	Estimate	t value
				Target Antonym				
Intercept	-	-	241.10	20.50*	-	-	250.72	17.23*
Affirmative Complementary	-	-	25.32	2.18*	-	-	48.96	3.11*
Negated Complementary	-	-	13.61	1.13	-	-	46.07	2.85*
Contrast	-	-	-11.71	0.98	-	-	2.89	0.18
				Post-Target Region				
Intercept	447.01	13.79*	594.13	13.18*	-1.27	7.24*	527.70	13.55*
Affirmative Complementary	-1.94	0.11	92.25	2.90*	0.61	3.40*	52.00	2.30*
Negated Complementary	39.06	2.22*	140.26	4.40*	0.36	1.97*	90.04	3.95*
Contrast	41.00	2.33*	48.00	1.50	-0.25	1.45	38.04	1.66
				Wrap-Up Region				
Intercept	1475.07	18.04*	1661.21	17.53*	-1.36	6.29*	1514.12	18.56*
Affirmative Complementary	-25.08	0.45	64.68	1.13	0.18	0.93	17.74	0.48
Negated Complementary	-103.86	1.94	35.08	0.61	0.20	1.04	-7.51	0.18
Contrast	-78.78	1.85	-29.6	0.52	0.02	0.11	-24.37	0.66

*Note. * t>1.96. Intercept refers to Negated Repetition condition. Affirmative Complementary and Negated Complementary refer to Contrasts to Repetition Condition. Contrast refers to Comparison between Negated Complementary and Affirmative Complementary.*

Table 5.6. Fixed effect estimates from the linear mixed-effects models for regressions in and total reading time of pre-target regions.

Measure	Bounded Regressions In		Bounded Total Reading Time		Unbounded Regressions In		Unbounded Total Reading Time	
Condition	Estimate	z value	Estimate	t value	Estimate	z value	Estimate	t value
First Sentence Context								
Intercept	-0.10	0.56	1525.64	14.18*	0.02	0.12	1338.18	11.75*
Affirmative Complementary	-0.23	1.43	12.67	0.27	-0.10	0.60	109.40	2.25*
Negated Complementary	0.04	0.27	19.91	0.42	0.16	0.32	94.70	1.95
Contrast	0.28	1.71	7.25	0.15	0.26	1.58	-14.71	0.30
First Antonym								
Intercept	-4.19	8.45*	208.95	11.20*	-4.25	8.33*	222.77	10.12*
Affirmative Complementary	0.09	0.15	39.80	2.44*	-0.04	0.07	30.37	1.82
Negated Complementary	2.39	4.91*	66.54	4.09*	2.25	4.84*	81.11	4.87*
Contrast	2.22	5.04*	26.75	1.65	2.30	4.97*	50.74	3.05*
Second Sentence Context								
Intercept	-1.12	6.53*	840.46	10.96*	-1.10	5.70*	811.64	10.70*
Affirmative Complementary	0.18	1.02	-7.78	0.24	0.31	1.71	23.56	0.59
Negated Complementary	0.62	3.05*	20.18	0.70	-0.24	1.19	-298.65	7.49*
Contrast	-0.79	3.97*	10.01	0.34	-0.54	2.78*	-322.21	8.08*

*Note. * t>1.96. Intercept refers to Negated Repetition condition. Affirmative Complementary and Negated Complementary refer to Contrasts to Repetition Condition. Contrast refers to Comparison between Negated Complementary and Affirmative Complementary.*

Discussion

Experiment 4 used measures of eye movements to investigate how readers incorporate bounded and unbounded affirmative items into their discourse representation, following a negated item. Evidence of effects on eye movement measures were found to suggest that readers experienced more processing difficulty in referring an antonym back to a previously mentioned negation (affirmative complementary), than the reverse (negated complementary), regardless of boundedness. Bounded negation complementary passages only produced disruption in reading times on the negated antonym, compared to the bounded repetition condition. In contrast, the bounded affirmative complementary passages produced disruptive reading patterns in the post-target region (more regressions out and longer go-past and total reading times), in addition to the target word. In the unbounded negated and affirmative complementary conditions, readers experienced disruption in both the target and post-target regions, relative to the repetition condition.

The results obtained for the negated complementary passages of Experiment 4 largely replicated the findings from Experiment 2. Bounded negated complementary passages produced longer go-past reading times and total reading times on the target, but no evidence of disruptive reading was evidenced in reading of text following the target antonym. Once again, it appeared the inferential processing required to assimilate two representations of high similarity occurred within a very rapid time course. To be clear, the previously stated antonym (*dead*) allowed for very rapid integration of the negated antonym (*not alive*), as they are seen as two states of very high semantic similarity. In contrast, both Experiment 2 and Experiment 4 found disruption in the unbounded negated complementary condition in the target and post-target region, relative to the unbounded repetition condition. Presumably, readers experienced processing difficulty downstream from the negated antonyms in the unbounded complementary conditions, and this reflected the inferential work required for the resolution of ambiguity. Readers must infer that the complementary negation (*not early*) could refer to a previously denoted state (*late*). This inference is required because the negation, in isolation, could refer to two possible states (i.e., *on time*, or *early*). Clearly, this inference was not required in the bounded negated

complementary condition, as the negation could only refer to one possible state (*not dead* must mean *alive*).

Next, consider the pattern of disruption found in the affirmative complementary condition. All previous results within this thesis have appeared to suggest readers interpret bounded negation as being synonymous with its antonym. In contrast, when readers were required to integrate the two statements the other way around readers exhibited great difficulty in their reading behaviour. It was predicted that readers would be able to rapidly integrate bounded affirmative complementary statements. Instead, readers exhibited longer go-past and total reading times on the target and post-target regions, as well as more regressions out of the post-target regions, relative to the bounded repetition condition. If readers had fully interpreted the bounded negation, it should have been easily integrated within its antonym later in the passage. The fact that this did not happen provided unexpected support for an underspecification account. As the semantic configuration of bounded concepts only featured two states, it was not possible for readers to instantiate a midpoint representation. Yet, readers still experienced processing difficulty when they fixated the antonym of the negated element that appeared earlier in the text. This suggested readers might have not been committing to a specific interpretation of the text, even when the negation was inherently unambiguous. As such, readers suffered delays to reading, suggesting some form of inferential processing. It would appear this was required in order to integrate the antonym into their discourse representation and update the previous interpretation of the negation.

Next, consider the unbounded affirmative complementary condition. As in the bounded case, it was found that readers experienced disruption to reading, compared to normal reading of the repetition condition. Disruption was reflected in longer go-past and total reading times on the target and post-target regions, as well as more regressions out of the post-target regions, relative to the unbounded repetition condition. Such a delay should have argued against an underspecification account, as readers were not able to rapidly adapt their underspecified representation to the actual state denoted in the text. The same pattern of effects were also found in the bounded affirmative complementary passages. No interaction of boundedness was found for any eye movement measures in the target region, and the pattern of effects for later measures and post target analyses were qualitatively similar for both the

bounded and unbounded affirmative complementary conditions. A 'midpoint' account, such as that suggested by Madden and Zwaan (2003) for the representation of aspect, cannot provide a theoretical explanation for these results. As no midpoint representation can be instantiated, readers should have experienced no difficulty in the bounded passages. Furthermore, the results of Experiments 1-3 have shown that bounded negation is interpreted as its antonym, and readers are capable of integrating the two very rapidly during natural reading. Rapid integration of bounded negation was not found when the negation was presented first. The disruptive reading patterns in the affirmative complementary passages would appear to be due to this position of the negation. As such, it could be reasonable to assume readers required a degree of referential processing, in order to establish the meaning of the target antonym with regard to the previous negation.

The current stimuli did not demand readers to establish coherence regarding the state of the key concept denoted within the passages, until they fixated the second antonym, when readers must establish coherence between the two antonym usages. As such, it was possible for readers to not fully define their interpretation of the negation in the affirmative complementary condition until they were forced to instantiate a representation coherent with the antonym presented. As the text is not inconsistent in anyway, the delays in reading would appear to be due to a lack of defined representation of the bounded negation, when presented in isolation. This created the need for referential processing of the antonym with the previous negation. In the case of the affirmative complementary condition, the findings offered no evidence to suggest processing of the unbounded passages were different from their bounded equivalent. As such, the results of Experiment 4 supported the notion that readers employ representation underspecification during language comprehension. As previously shown, when ambiguous text does not present a definitive state, readers choose to underspecify their representation (Pickering et al., 2006; Slattery et al., 2013).

It would appear that readers were not fully interpreting the negated antonym in the affirmative complementary condition. Negated items are interpreted as providing a non-literal meaning by default. As explained with Dynamic Pragmatic accounts of negation, negative operators are considered to be multifunctional, as they do not only suggest the absence of a concept, as was presented in previous theories of

negation (e.g. Kaup & Zwaan, 2003; MacDonald & Just, 1989). One of the functions, it has been suggested, is to indicate a non-literal meaning. The passages within this thesis were designed to not constrain a reader to expect a specific interpretation of the negated item. In the previous studies within this thesis, the comprehension of negated phrases was investigated when they caused semantic inconsistency. This was not the case, however, in the negated affirmative condition, where the negation was presented without any inconsistency. As such, it is perfectly possible that readers generated multiple interpretations of the negation, including non-literal interpretations. As such, it could be that readers experienced difficulty when they were required to adapt their representation to a literal interpretation of the text.

For instance, Giora et al.'s (2013) corpus analysis found negation is very likely (up to 92%) to be used to denote sarcasm, a non-literal interpretation of negation. Furthermore, when presented in isolation, negated items were rated as being more sarcastic than affirmative equivalents (*supportive she is not* was rated as more sarcastic than *supportive she is*). Finally, they found readers read negated items more quickly when presented within sarcastic contextual frames than when presented literally. As a result, Giora et al. argued that when presented without semantic anomaly or no incongruity to pragmatic information, negation causes readers to generate non-literal interpretations. While it is highly unlikely that readers were generating a sarcastic interpretation of the negations when reading these passages, this helps to illustrate the fact that readers can be led to generate more readings of text than just the literal interpretation when presented with a negation.

Another issue that required consideration in light of these results was that of reading strategy. In this study, participants were required to read 72 paragraphs detailing two characters either agreeing or disagreeing on a key concept. Unlike previous experiments, however, there was no incongruent condition present, meaning readers were never faced with anomalous text. In Experiments 2 and 3, anomalous text has clearly been shown to cause readers serious delays in reading. The lack of serious disruption to reading in the current experiment may have led to less systematic reading strategies when faced with similarly structured passages. As such, it is possible that readers were less likely to suffer delays in reading, as there was no need to develop a reading strategy that would help to accommodate any potential anomalous text into reading. Past research has clearly shown task effects on

reading strategies, such as increased skipping and faster fixation durations when skim reading (Just & Carpenter, 1980; Fitzsimmons; Weal & Drieghe, 2014) and when reading text again (Raney & Rayner, 1996). Recent evidence suggests this does not affect anomaly-reading effects over the time of a single reading experiment (Weiss, Kretzschmar, Schlesewsky, Bornkessel-Schlesewsky & Staub, 2018). It is perfectly possible, however, that anomalous passages affect the reading of other passages, as readers develop strategies in acknowledgement of the difficulty processing anomalous passages of text causes. Explicit manipulation of this in further research would add to our understanding of this phenomenon.

Further research is required to investigate the degree to which readers are generating non-literal interpretations of negation by default, and if this is modulated by the boundedness of the negated element. For instance, the manipulation of Experiment 4 could be conducted with literal and sarcastic contextual frames, in order to test whether readers experience more difficulty adapting their interpretation of a literal negation (as in the affirmative complementary condition), following a sarcastic contextual frame, and whether this is affected by boundedness. Evidence such as this would strengthen the notion that negation generates non-literal interpretations by default. Further research could concern the timecourse within which participants commit to negated representations. Further research is required to differentiate what linguistic contexts cause readers to commit to specific representations, especially in the case of unbounded entities, where their ambiguity can be relieved from previous or subsequent content. The contextual frames of the current study did not attempt to constrain a readers' interpretation of the negation. It would be expected that biasing contexts would allow for less disruption in the affirmative complementary conditions, as readers do not need to alter their interpretation of text at the point of the target word.

In conclusion, Experiment 4 provided novel evidence to suggest that it is cognitively more demanding to integrate an affirmative bounded or unbounded word with its negated antonym, than it is to integrate the two in the opposite order. This suggests readers do not specify their representation of negation unless it is required in order to prevent a lack of coherence within the text. Further ambiguity of negation could be generated from the fact that negation is often used to generate a non-literal interpretation of the negated item.

Chapter 6

General Discussion

The aim of this thesis was to investigate the effect of the linguistic operator of boundedness during language comprehension. To reiterate, boundedness refers to the semantic configuration of concepts (Paradis & Willners, 2006). Bounded items express two categorical, mutually exclusive and mutually exhaustive opposites (e.g. *alive-dead*). Due to these characteristics, a bounded negation should be semantically identical to its antonym. In contrast, unbounded items express more scalar dimensions, with varying degrees of the concept in between each polar antonym (e.g. *wide-narrow*). This means the negation of an unbounded item is not necessarily interpreted as its antonym, as the two polar states are not mutually exhaustive of all states within that concept. For example, if someone is *not dead* they must be *alive*, but something that is *not wide*, is not necessarily *narrow*.

Within this thesis, a large amount of data has been collected concerning how people interpret bounded and unbounded negation. Firstly, an offline similarity judgment rating experiment investigated boundedness interpretation within a single sentence. This provided the theoretical foundations for predictions of the on-line effects of boundedness upon language comprehension. From the offline studies, it was found that participants were sensitive to the linguistic operator of boundedness within short contexts when providing similarity ratings. Subsequently, a series of eye movement experiments were conducted, which consistently found readers were sensitive to the manipulation of boundedness during natural reading. Specifically, boundedness affected the integration of text during on-line written language comprehension, suggesting it plays a role in the unfolding instantiation of a discourse representation. Boundedness is a subtle linguistic operator. Nevertheless, through rigorous pretesting, and controlled passages of text, this research has helped us to understand the role of boundedness in language comprehension.

Findings, Implications and Contributions

Chapter 2: Investigating Readers' Interpretations of Boundedness During Offline Judgement Tasks

Within Chapter 2, the following research questions were investigated:

- *Experiment 1a: Does antonym prevalence vary as a function of boundedness?*
- *Experiment 1b: Are readers sensitive to the linguistic operator of boundedness when reading sentential negation?*
- *Experiment 1c: Are readers sensitive to the linguistic operator of boundedness when it is presented within a passage context?*

In Chapter 2, Experiment 1a explored whether antonym prevalence varied across bounded and unbounded antonym pairs. Antonym prevalence refers to how often any single antonym is considered the opposite of a word. Boundedness was manipulated, in order to investigate whether readers provided the same "best single word opposites" for bounded and unbounded antonyms. Furthermore, this ensured that the stimuli (the antonym pairs) to be used in subsequent experiments did not differ on an important semantic variable (that of antonym canonicity). In Experiment 1b, readers' sensitivity to the linguistic operator of boundedness was investigated. This was measured using similarity ratings, which participants provided after reading two short sentences featuring an unbounded negation, and its antonym. In Experiment 1c, readers' sensitivity to the manipulation of boundedness was further explored by placing the antonyms in a passage context where two characters used various antonym combinations. The passages featured two antonyms, which were repetitious (e.g. *not dead - not dead*), incongruent (e.g. *not dead – not alive*) or complementary (e.g. *dead – not alive*) of one another. This allowed for investigation not just of similarity (in the complementary condition), but also the mutual exhaustiveness of two negations (i.e. the incongruent condition).

The rationale behind these three experiments was to provide a bottom up approach, with these offline ratings providing clear theoretical reasoning for the

predictions made in subsequent experiments. The results of this set of experiments also illustrated that the stimulus set adhered to the principles of boundedness (Paradis, 2001; 2005; Paradis & Willners, 2006) and confirmed that that they were suitable for investigating this phenomenon.

Experiment 1a demonstrated that bounded and unbounded antonym pairs did not differ in the relationship shared between each member antonym. There was no difference in how often (%) each antonym was elicited by the other between the bounded and unbounded items. The results of Experiment 1a, therefore, provided a set of 36 bounded and 36 unbounded antonym pairs, which did not differ in the strength of their antonymic relationship.

Experiment 1b demonstrated that, when making similarity judgments about sentences, readers were sensitive to the manipulation of boundedness. As participants rated two sentences together, these ratings were based on their ultimate interpretation of the text. The results of Experiment 1b replicated those found in previous studies of boundedness (Fraenkel & Schul, 2008; Paradis & Willners, 2006;). Specifically, readers rated bounded negation as being more similar to its antonym than unbounded negation. For example, *not dead* was interpreted as being more semantically similar to *alive* than *not wide* was to *narrow*. These findings met the predictions provided within the boundedness hypothesis (Paradis & Willners, 2006). As two bounded states are mutually exclusive, (i.e. one cannot be *alive* and *dead*), and those states are mutually exhaustive (i.e. one must be *alive* or *dead*), bounded negation was interpreted as its antonym. This is unsurprising, considering there were no logical alternative states that could be interpreted from a bounded negation. In contrast, the two states indicated by unbounded antonyms are not mutually exhaustive of each other (i.e. outside of *wide* and *narrow* are a theoretically infinite number of states of varying *width*). Furthermore, as unbounded states are less 'absolute' and based on subjective experience (Kennedy & McNally, 2005), it could be argued that two unbounded states are not mutually exclusive of each other. For example, one could consider a basketball player to be *tall* in the context of all people, but *short* in the context of other basketball players. As a result, readers did not interpret unbounded negation as referring to a state synonymous with its antonym.

Experiment 1c replicated this effect when the bounded and unbounded negations were presented within passage contexts. In the complementary condition,

readers still interpreted bounded negation as more similar to its antonym than unbounded negation. The results of Experiment 1c made an important contribution to the negation literature, as, to date, there are no investigations of how boundedness is interpreted within extended contexts, even though negation interpretation has been to shown to be affected by context (Anderson et al., 2010; Beltran et al., 2008; Nieuwland & Kuperberg, 2008; Nordmeyer & Frank, 2014).

A further finding from Experiment 1c concerned the contradictory condition. Specifically, it was found that two bounded negations (e.g. *not alive – not dead*) were considered to be less semantically similar from each other than two unbounded negations (e.g. *not late – not early*). Once again, these results are unsurprising given what would be predicted from our understanding of boundedness. As bounded negation is interpreted as being very similar to its antonym (as seen in Experiment 1b and the complementary condition of 1c) the two bounded negations should be considered as two polar antonyms. As such, it was unsurprising that participants considered these two states to be very different from each other. In contrast, unbounded negation was not considered as similar to its antonym. Two unbounded antonyms are not mutually exhaustive of that concept, due to alternative states in between. As such, readers displayed sensitivity for the other states that could be presented by two unbounded negations. For example, *not late* and *not early* could be interpreted as both referring to the state of *on time*. As both unbounded negations could be referring to a similar state, they were interpreted as being more similar than bounded negation. These results provided further evidence to suggest readers are sensitive to the linguistic operator of boundedness during language comprehension.

Limitations and Future Research

The results of these three experiments served as the foundation for future experimentation using eye movement methodology to examine reading behavior on text featuring bounded and unbounded negation. By collecting these offline data, it was possible to make several theoretically motivated predictions about the reading of bounded and unbounded negation. By basing future experiments in this thesis upon the use of eye movements during natural reading, it was possible to build an understanding of how readers process boundedness. This is particularly advantageous considering that eye movements provide a non-invasive measure that

reflects online processing of text (Liversedge & Findlay, 2000; Rayner, 1998; 2009). A possible limitation of Experiment 1a concerns the use of the antonym elicitation methodology. While a valid task for collecting antonym canonicity data (Murphy & Andrew, 1993; Van de Weijer, Paradis, Willners & Lindgren, 2012), corpus analysis has also shown that the measure of antonym co-occurrence also offers a valid index of antonym canonicity (Justeson & Katz, 1991). Corpus analysis also has the advantage of showing common patterns in actual language use, making it a highly valid measure. In the case of antonym canonicity, however, it has been shown that corpus data marry very closely with those found using offline response methodologies (Paradis, Willners & Jones, 2009) reducing this limitation.

A limitation of Experiment 1b was that it only explored the use of negation within short sentences. This, however, was addressed through the use of passage contexts in Experiment 1c, with Experiment 1b providing important motivation for further investigation of this stimulus set.

Nevertheless, there is still the task effect to consider in Experiments 1b and 1c. The similarity-rating task used in these experiments demanded an explicit comparison between two antonyms (of which at least one was negated). While insightful, these findings only provided information as to how readers are sensitive to boundedness when considering their ultimate interpretation of text within an explicit judgment task. The experiment reported in Chapter 3, however, addressed this issue by exploring how readers process passages of text featuring conflicting and complementary bounded and unbounded negation. This provided a realistic assessment of the way in which readers integrate bounded and unbounded negations during natural language comprehension. Furthermore, this allowed for theoretically motivated speculation as to how readers encode boundedness into their discourse representation.

Chapter 3: An Eye Movement Investigation of the Processing of Negated Bounded and Unbounded Expressions During Reading

Within Chapter 3, the following research question was investigated:

- *Experiment 2: Is negation processed differentially on-line during reading as a result of a negated element's boundedness?*

In Chapter 3, it was investigated whether readers were sensitive to the manipulation of boundedness during on-line processing of text. Passages were carefully constructed in order to investigate the timecourse of the processing of bounded and unbounded negation. Specifically, there were two antonym usages, with the second antonym either being repetitious, incongruent or complementary with the previous. The second antonym acting as a target region, meaning it was possible to investigate the time course of readers in detecting any semantic inconsistency (manifested in longer fixations and more regressive eye movements), from this point until the end of the reading of the passages.

The first key finding of Experiment 2 was a qualitatively different oculomotor response to the target antonym in the bounded and unbounded incongruent conditions. In the case of bounded incongruent passages, readers evidenced no increase in fixation times, but made an increased proportion of regressive saccades back into the text. Presumably, the logical contradiction present between two bounded negations was so immediately anomalous that participants rapidly detected it. This caused immediate regressive eye movements back into the text to check their interpretation (as seen in previous anomaly studies; see Braze et al., 2002; Murray & Rowan, 1998; Rayner et al., 2004; Traxler et al., 2000; Warren & McConnell, 2007). In contrast, unbounded incongruent (and unbounded complementary) passages led to increased fixation times on the target word. Disruption to reading in the unbounded incongruent condition was not as severe as in the bounded case. This disruption was taken to reflect inferential processing necessary to integrate two unbounded expressions that are not mutually exclusive. The evidence provided here suggested that on-line negation processing is affected by the semantic configuration of the negated entity.

Contrary to many theories of negation, these results indicate a very immediate sensitivity to the contradiction/incongruence that was present within the passages of

text, despite them being expressed by a negated element. Many theories of negation, such as two-step (Kaup, 2001; Kaup, 2011; Kaup & Zwaan, 2003) and propositional theory (Chase & Clark, 1971; Clark & Chase, 1972; Just & Clark, 1973; Just & McDonald, 1989) argue that because negation is representationally more complex, interpretation of that element will always be delayed. In the eye movement measures presented in Experiment 2, however, it was clear that there must be some level of immediate interpretation of the negated elements, or readers would not have been able to detect any inconsistency within the text. The data from Experiment 2 appeared to indicate that at least some aspects of negation are computed quickly. Furthermore, the use of eye movement methodology affords the potential to identify subtle differences in negation processing. The findings from Experiment 2 can be integrated into a Dynamic Pragmatic account of negation. Primarily because Dynamic Pragmatic accounts allow for boundedness to be processed during incremental interpretation, that is, negation is subject to semantic processing at the point at which it is read (Tian & Breheny, 2016). Boundedness must be considered as an important pragmatic variable when assessing the number of alternatives that can be construed from a negation. The data here, however, provided a temporally sensitive measure of processing, providing a much richer data set relating to the time course of negation processing. For these reasons, it should be considered that using eye movement recordings to investigate processing of negation in reading is a valuable approach for future research.

The second key finding from Experiment 2 concerned the differential processing of bounded incongruent passages relative to the bounded repetition and complementary conditions. While bounded complementary passages caused very little disruption to reading, severe disruption was observed in the reading of bounded incongruent passages, through to the end of the reading of those passages. These results confirmed the predictions generated from Experiments 1a-c. As readers interpreted bounded negation as being very similar to its antonym, there was very little processing cost in integrating the two. Also as a direct consequence of this, two bounded incongruent negations were interpreted as a logical contradiction, with readers seemingly unable to integrate these two mutually exclusive states. Clearly, readers were sensitive to the manipulation of passage type, with clear effects on oculomotor behavior evidenced as such.

The third key finding from Experiment 2 concerned the differential processing of unbounded incongruent and complementary passages, relative to the unbounded repetition condition. In both the unbounded incongruent and complementary passages, disruption was observed on both the target and post target regions, with the resumption of normal reading by the final sentence of the passage. These effects were interpreted as being based on the degree to which inferential processing that was necessary to reconcile the two negated antonyms. As was found in the offline rating studies, participants consider both unbounded incongruent and complementary antonyms to be semantically dissimilar. This is as a direct result of the ambiguity within unbounded negation, due to alternative states within unbounded dimensions. Accordingly, readers displayed disruptive reading patterns in these conditions, as they undertook inferential processing to find a conciliatory state within the two ambiguous negations. Specifically, in the unbounded incongruent condition (*not early*, *not late*), while it is possible to reconcile the two negated antonyms (i.e., *on time*), an inferred state that is not explicitly denoted within the text must be attained. Similarly, readers must infer that the complementary negation (*not early*) could refer to a previously denoted state (*late*). This inference is required because the negation, in isolation, could refer to two possible states (i.e., *on time*, or *early*). Importantly, readers were sensitive to this ambiguity, and appeared to commence some form of ambiguity resolution processing in order to overcome it.

In sum, Experiment 2 provided novel evidence that boundedness affected the semantic interpretation of negation during online sentence comprehension. The findings of Experiment 2 indicate that readers are highly sensitive to the boundedness of a negated element and that this information is fundamentally formative in relation to the nature of the reader's developing representation of the discourse. More generally, this experiment is the first to provide evidence that boundedness has an early influence on the on-line processing of negation during natural reading.

Limitations and Future Research

As previously stated, the findings from Experiment 2 have shown that eye movement investigations of reading provide data that represent a measure of high temporal resolution that is a rich source of information as to the nature and time

course of negation processing. Yet, with the exception of Ferguson et al. (2008), where negation was used to analyse counterfactual processing, there is a complete lack of eye movement research investigating explicit negation processing. This is even more surprising, considering the theoretical advances made through experiments using eye movement methodology and in other areas of research investigating reading. Consider research into focus operators, such as *only*, where it has been found that readers use this information to constrain their expectations of upcoming text to include a contrast set (Liversedge, Paterson & Clayes, 2002). Also consider research into concessive connectives, where it has been shown they effectively allow readers to reverse their expectations of interclausal continuity (Kohne & Demberg, 2013; furthermore, conciliatory ERP findings are reported by Xiang & Kuperberg, 2015). By using online measures, these research areas have shown that subtle semantic effects of negated elements of text are processed online, and sophisticated interpretations of language processing have been generated as a result. To advance our knowledge of how negation is processed during natural reading, and to build a realistic theoretical account of how it is processed, clearly, further analysis of negation using on-line measures of processing is required.

One area for future research investigating boundedness and negation processing is the notion that there are different types of unbounded scale. For instance, there are unbounded concepts, where an unbounded negated antonym could refer to *only* two other states. For example, *not early* only refers to two other states: either *late* or *on time.* There are also unbounded concepts, where the negation can refer to much more than three possible states. *Not wide,* for instance, can refer to many (theoretically infinite) possible states along a scale ranging from *narrow* to an intermediate position within the entity's scalar ontology. Further research will need to determine more precisely the relationship between number of states and access to negated content. Recall that the inferential work readers undertook to resolve the ambiguity of unbounded negation largely explained the results of the unbounded passages. It is reasonable; therefore, that this would generate the prediction that three state negations should be interpreted with less ambiguity than scalar negation. This hypothesis requires empirical examination.

Chapter 4: An Eye Movement Investigation of the Effects of Connectives on the Processing of Boundedness and Negation

In Chapter 4 the following research question was investigated:

- *Experiment 3: Is the facilitatory effect of a connective modulated by the boundedness of a negated element?*

In Chapter 4, the effect of boundedness during language comprehension was investigated further. This was done, specifically, by introducing connectives into the passages of text. Connectives, when used correctly, are known to facilitate processing of multiple clauses of text (Cozijn, 2001; Kuperberg et al., 2011; Traxler et al, 1997a, 1997b). It has been suggested that this is because connectives indicate the relationship between upcoming and previous text. By indicating whether upcoming text is continuous or discontinuous, readers constrain their expectations accordingly, allowing for facilitatory processing of text when these expectations are met. In Experiments 1a-c and Experiment 2, it was established that bounded negation is interpreted with little ambiguity, as it denotes a categorical state. In contrast, readers appear to be sensitive to the ambiguous nature of unbounded negation, with both incongruent and complementary negations requiring inferential processing in order to be disambiguated. Experiment 3 investigated whether a connective could alleviate the disruption to reading that arises due to discontinuities within bounded and unbounded incongruent and complementary negations.

The first key finding of Experiment 3 was the early facilitation observed (manifested in shorter first fixation and gaze durations on the target) in the reading of bounded complementary passages when a connective was placed in between the two antonym usages. As bounded negation is unambiguous, it can be rapidly integrated with its antonym into a conciliatory discourse representation. The lack of delay in the representation of the bounded negation meant the integrative facilitation provided by a connective occurred within a very early time course. These findings are easily integrated with our knowledge of boundedness, specifically, the notion that a bounded negations' similarity to its antonym allows for rapid integration of that negation.

The second key finding of Experiment 3 was the relatively late facilitation (manifested in shorter go past reading times and fewer regressions out of the target

region) observed in the reading of unbounded complementary passages when a connective was placed in between the two antonym usages. It had previously been found that unbounded negation was not interpreted as a state similar to its antonym (Experiments 1b and 1c), with inferential processing required in integrating one with the other (Experiment 2). This finding from Experiment 3 provides evidence to suggest the slow representation of unbounded negation delayed the facilitation to integrative processing that connectives provide. Previous studies have suggested unbounded negation is more slowly instantiated into discourse than bounded negation (Anderson et al., 2011; Du et al., 2014; Paradis & Willners, 2006). Furthermore, Experiment 2 found unbounded complementary negation caused delays to reading, possibly due to the level of inferential processing required in integrating an unbounded negation with its antonym. Two explanations for the unbounded results follow from here. Firstly, the fact that negation is slowly instantiated means readers cannot begin to integrate multiple representations until later, compared to bounded negation. To be clear, readers cannot integrate two representations until the second has been fully represented. Secondly, the inferential processing load of unbounded complementary negation caused a delay in the integrative facilitation provided by a connective. This appears to suggest that the facilitatory role of the connective laid in its ability to increase the speed of integrative processing, rather than allowing readers to represent negation more quickly.

The final key finding of Experiment 3 was the lack of facilitation observed in the reading of both bounded incongruent passages, even when an appropriate connective was placed in between the two antonym usages. It has already been shown that readers consider two bounded negations to be very different from each other, due to the categorical semantic configuration of bounded concepts. Furthermore, readers did not return to normal reading patterns once they had read a bounded contradictory negation. Two bounded incongruent negations were interpreted as a logical contradiction, with readers seemingly unable to integrate these two mutually exclusive states. The reading effects found were likened to those found in semantic anomaly effects (i.e. immediate recognition of the anomaly via regressions out of the target word). This suggested that a logical contradiction could not be satisfactorily integrated into a single coherent discourse representation. These two states are categorically opposite of each other, and are mutually exclusive. As

previously stated, a connective facilitates processing by allowing readers to integrate multiple representations together. Readers constrain their expectations accordingly, allowing for facilitatory processing of text when these expectations are met. This integrative facilitation, however, cannot occur when readers are simply unable to interpret the negation in non-anomalous manner. As such, while the use of a connective can have an initial facilitatory influence on bounded complementary negation, it still cannot prevent readers from suffering the disruption associated with bounded incongruent negation, due to the logical contradiction present.

In sum, the results of Experiment 3 provided further evidence to suggest readers are sensitive to boundedness during on-line text comprehension. When readers are provided with connectives to indicate that relationship between sentences, they constrain their expectations of upcoming text. The effects these constraints have on text processing are modulated by the variable of boundedness.

Limitations and Future Research

One limitation of Experiment 3 is the use of a different connective in the incongruent condition compared to the repetition and complementary conditions. In order to investigate how readers used connectives to interpret bounded and unbounded negation, connectives were used that always matched the continuity status of the two antonym usages. As such, incongruent conditions featured an adversative connective, due to the two incongruent negations, whereas the repetition and complementary conditions featured causal connectives. There is research, however, to suggest that adversative connectives are inherently more complex and, as a result, more slowly interpreted. Caron et al. (1988) found poorer memory recall for adversatively connected sentences than causally connected. Kohne and Demberg (2012) found poorer comprehension accuracy for adversatively related clauses than causally related clauses, despite facilitation in the reading of both. Finally, Xu et al. (2017) reported slower self-paced reading times and slower detections of anomalies in eye movement measures for adversatively related sentences, compared to causally related sentences. The results of the incongruent condition in Experiment 3 could be taken as further evidence to support the notion that adversative connectives are more difficult to integrate than causal connectives.

Adversative connectives indicate that upcoming text will contain an element of suprisal and presupposition from the previous clause. In contrast, causal connectives indicate that the causal relationship that is assumed throughout text (Murray, 1998) will be maintained. Hence, it has been suggested that the former connective type is more costly in terms of processing. Further research is required to disentangle the effects of connectives in the processing of bounded and unbounded incongruences. The placement of connectives that did not fit with the discourse relation between two antonym usages was considered for this experiment (e.g.. *not dead*, *therefore, not alive*). Such was the lack of coherence created by sentences such as these, that it was considered they would cause readers to possibly adopt a reading strategy that is unlike natural reading for comprehension. It was, therefore, judged that stimuli set that lacked such coherence would interfere with reading behavior and invalidated any findings within this experiment. As such, it was considered outside the scope of Experiment 3. Clearly, this research question requires further investigation.

Further research could also consider the nature of epistemic markers in the processing of bounded and unbounded text. As already noted, readers have previously shown a sensitivity to the manipulation of subjectivity when it is encoded into text (Canestrelli, et al., 2013; Traxler et al., 1997). Specifically, readers are more capable of encoding relations that are only causal in the view of the communicator when presented with epistemic markers (such as *I think…*). Further research should investigate whether this could alleviate any integration delays in the reading of the bounded and unbounded passages. If Experiment 3 were re-run with epistemic markers, it could be argued that this may help to assuage delays in the incongruent condition. The fact that bounded concepts, however, appear to be based more upon categorical states, whereas unbounded concepts are more based on subjective inference (Kennedy & McNally, 2005) could also mean boundedness modulates the use of epistemic markers. Rather than needing to infer a possible state, it may be possible to take the epistemic markers to show the unbounded items are based on subjective inference, alleviating any reading delays. In contrast, bounded items are based more on objective fact. It could be argued, therefore, that disruption in the reading of bounded incongruences would not be alleviated through the use of epistemic markers. Further research is required to investigate this hypothesis and investigate the effects of subjectivity upon boundedness interpretation.

Chapter 5: An Eye Movement Investigation into the Nature of Unbounded Negated Representations

In Chapter 5, the following research question was investigated:

Experiment 4: How do readers interpret unbounded negation in isolation?

In Chapter 5, the passages from previous experiments were adapted again, in order to investigate how readers interpret unbounded negation further. An additional condition was introduced, whereby the complementary antonym orders were reversed (affirmative complementary condition, e.g. *not early-late*). While the negated complementary condition (e.g. *early-not late*) investigated how readers interpreted a negation with its antonym, the reverse was explored in the affirmative complementary condition. Specifically, this tested how readers had chosen to interpret an antonym, with any reading disruption acting as an index of how similar the previous interpretation was to the affirmative antonym (which acted as the target word). As such, this condition revealed readers' interpretation of a negation.

In the bounded case, very little disruption to reading was predicted. As bounded negation is unambiguously interpreted as its antonym and rapidly integrated (Experiments 1a-c, 2 and 3), the antonym should match the previously interpreted negation (e.g. *alive* is interpreted as with *not dead* very quickly). In the unbounded case, however, two theoretical hypotheses were proposed from previous psycholinguistic literature on how readers overcome ambiguity during language comprehension. Due to the fact that readers do not consider unbounded negation to be similar to its antonym (Experiments 1a-c) and the fact readers struggle to integrate the two during on-line language processing (Experiments 2 and 3), it was reasonable to suggest readers do not interpret unbounded negation as its antonym.

The first hypothesis was that readers overcome ambiguous items by instantiating multiple midpoint interpretations (Madden & Zwaan, 2003). If this were the case, it was expected that unbounded affirmative complementary passages would cause more disruption to the reading of the target antonym than their bounded equivalents. If readers had interpreted the negation as a midpoint state, they would have had to adjust their interpretation when explicitly told that it was the antonym of the negated element. The second, alternative hypothesis suggested that readers

choose to underspecify their interpretation when they encounter an ambiguous term (Pickering et al., 2006). To be clear, underspecification refers to the process whereby readers do not commit to a specific interpretation of text and do not instantiate a fully defined representation of discourse (Frisson, 2009). If this were the case, then it was expected that readers would not suffer any further disruption in the reading of the target antonym in unbounded affirmative complementary passages, compared to their bounded equivalents. As readers have not fully interpreted the negation, due to its ambiguity, they should have been able to rapidly accommodate the antonym, disambiguating an underspecified element of their discourse representation.

The key finding of Experiment 4 was that there was no interactive effect of boundedness on the processing of the target antonym in the affirmative complementary condition. This result could be integrated with an underspecification account of ambiguity resolution during language processing. If readers were underspecifying the preceding negation, then it would explain how readers were able to rapidly integrate the antonym with a previous negation. As such, Experiment 4 adds to a growing literature that has found readers often do not instantiate a fully defined representation of discourse, especially when faced with a semantic ambiguity (Ferrera et al., 2002; Frazier & Rayner, 1987; Frisson & Pickering 2001; Sturt et al, 2013). Furthermore, it extends our knowledge of how unbounded elements are interpreted. Specifically, it would appear that without any disambiguating information, readers choose to underspecify their interpretation of unbounded negation. Furthermore, it was of interest that the affirmative complementary condition yielded disruptive reading patterns, compared to the repetition condition, even in the bounded dataset. This was unexpected, given the fact that bounded negation is unambiguous, and should be interpreted as its antonym. These results suggested negation is often underspecified, possibly because the stimuli set did not force readers to select an interpretation until the point of the second antonym (the target). Despite the fact that unbounded negation is unambiguous, it would appear that negation can still cause multiple interpretations, especially in light of evidence suggesting negation generates non-literal interpretations by default (Giora et al., 2013).

Limitations and Future Research

One limitation of Experiment 4 concerns the fact that the key finding is essentially a null result (in terms of an interaction between boundedness and passage type). The failure to reject a null hypothesis creates the concern that a Type II error could have occurred. Eye movement measures, however, such as those analyzed in Experiment 4, have been shown to be a highly sensitive measure to the effects of language manipulations, especially those concerning underspecification (see Pickering et al., 2006; Rayner, 1998). Experiments 2 and 3 have shown that eye tracking measures are a reliable indicator of whether readers are sensitive to boundedness during the processing of text. Furthermore, the study also offered a replication of Experiment 2, in that readers showed comparable reading delays in the unbounded negated complementary condition across both experiments. Readers showed sensitivity to boundedness during online comprehension of text has been reliably found across multiple experiments. Eye movement measures have been shown to produce robust findings with regard to the high-level semantic variable of boundedness. As such, it is suggested that Experiment 4 was sufficiently sensitive to detect different integration processes for the reading of bounded and unbounded negation. Nevertheless, as Experiments 2-4 represent some of the first attempts to explore the effects of boundedness on on-line language processing, replication is still required and should be attempted in further research.

The findings of Experiment 4 provide an understanding of how readers interpret bounded and unbounded negations, relative to their antonym. It was found that, with no other cues, readers underspecify their interpretation of negation. Further research could investigate what factors can constrain readers to specify this representation. For instance, Filik, Howman, Ralph-Nearman and Giora (2017) found readers often generate non-literal interpretations of negated phrases during offline ratings, and process negation faster within contexts that encourage that non-literal meaning. This suggested readers do generate interpretations of negation dependent on the constraints supplied by the context. Further research is required to disentangle other contextual and pragmatic uses of negation. Finally, if it is true that bounded negation is unambiguous and rapidly interpreted as categorical, then contextual information should not affect the processing of bounded negation.

One particular variable of interest could be reading skill/language ability. Previous studies have found less skilled readers are more likely to not detect anomalous text (Hannon & Daneman, 2004; Long & Chong, 2001). Considering the perceived subtlety of boundedness, it would be unsurprising if these effects were replicated for our boundedness passages (i.e. decreased probability of detecting unbounded incongruences/complementary inconsistencies in less skilled readers). This is particularly relevant in the reading of unbounded negation where less skilled readers may be much more likely to engage in shallow processing of the text (i.e. not instantiate a fully defined representation) due to its ambiguity. As such, it may mean they are able to less appreciate the semantic inconsistency within unbounded passages of text.

Recall from the discussion in this chapter of Experiment 2, where different unbounded concepts were discussed. Specifically, three state unbounded concepts (such as *early-late* where the alternative state is *on time*) and scalar unbounded concepts (such as *hot-cold* where there are theoretically infinite degrees of heat). While the findings of Experiment 4 (i.e. a lack of interaction for eye movement measures) between bounded and unbounded affirmative complementary passages were taken to suggest readers underspecify their representation of negation. This is very plausible in the scalar cases, where the negation could be interpreted as any number of states. In the three state cases, however, the negation can only suggest two alternatives, meaning that negation is theoretically less ambiguous than scalar negation, where there a theoretically infinite alternative states. It could be the case that readers are more likely to commit to a specific representation of the midpoint state, due to the lack of ambiguity relative to scalar concepts. Supplemental analyses were conducted on the data of both Experiment 2 and 4, and found no modulatory effect of this variable on the reading of unbounded passage. Nevertheless, an experimental manipulation is required to empirically test this research question.

Final Conclusions

Negation

In the literature review, 50 years of negation research was reviewed, with the conclusion that only with the Dynamic Pragmatic account researchers were

considering the large number of contexts within which negation can occur. This was in contrast to propositional theory, which often only considered single sentence negation (Chase & Clark, 1971; Clark & Chase, 1972; Just & Clark, 1973; Just & McDonald, 1989), and two-step theory, which often explained negation as signaling an absence (Kaup, 2001; Kaup, 2011; Kaup & Zwaan, 2003). If we consider these three theories, it is clear that the results of the experiments within this thesis provide evidence mostly for a Dynamic Pragmatic Account of negation processing. In all three on-line experiments, we found immediate detection of a semantic anomaly/inconsistency on the target word. Such results cannot be integrated with an account that predicts a universal delay in the processing of negation, such as two-step theory and propositional theory.

From the outset of this thesis, it was suggested that Dynamic Pragmatic theory offered the strongest account of negation processing. Before the work undertaken in this thesis, it was established that negation could be processed rapidly if used in a context where its use was pragmatically efficient (Giora, 2006). Negation is computationally more complex than affirmation, due to the addition of a negative operator. This does not, however, mean that negation must be harder to process than affirmation. Despite several experiments to the contrary, it would appear that negation is only harder to process than affirmation when pragmatic motivation for the use of that negation has not been provided. For instance, when providing plausible denial, it has previously been shown that the processing of negation is relatively rapid. For instance, communicating that *the train was not late* is functionally vapid unless some other pragmatic function is being served, such as denying a previous supposition of the interlocutor who assumed *the train was late*, as that is the usual situation (De Villiers & Flusberg, 1975; Wason, 1965). Furthermore, when readers are expecting a contrast, negation is also relatively rapid (Nieuwland & Kuperberg, 2008; Tian et al., 2010; 2016). For instance, when text signifies that text will feature a contrast, it constrains a reader's expectation that negation will feature in upcoming text, as it is a common contrastive element. For instance, through clefting (*it was*) or presuppositional context that encourages readers to expect a contrast. It is in this manner, that negation is not necessarily more complex than affirmation, but it does require readers to understand why that negation is being used. Without a clear

pragmatic motivation for its use, negation is heavily ambiguous (Givon, 1978) and processed much more slowly.

The ambiguity inherent within negation use can also be reduced when it is clear that there is only one alternative state that can be denoted. As such, negation with this lack of ambiguity is also processed more quickly than negation with many alternatives. Unambiguous negation includes negative operators that encompass a bounded item (*alive/dead*) (Paradis & Willners, 2006), a lexical item with a clear contrastive antonym (*tidy/messy*, Mayo et al., 2004), or a negation featured within a contextual frame to constrain only one alternative (*a coin not head/tails up*, Anderson, et al., 2010). Due to the simplified selection of a semantic state, the instantiation of these types of representation is rapid, and available via processes of incremental interpretation (Tian & Breheny, 2016). More inferential processing is required in order to understand negated representations referring to multiple possible states. This is the case when the negation is unbounded (e.g., *wide/narrow*), lacks a clear contrastive item (e.g., *adventurous*), or lacks constraint by context (e.g., *the coin is not in the air*, Anderson et al., 2010). In this case, the instantiation of a representation of the negation is much less immediate due to its ambiguity. Evidence has been provided to suggest the number of alternatives created by a negation affects the negation interpretation during natural reading. Empirical support is provided to suggest that the notion that the number of possible representations a negated expression can be interpreted as affects the nature of how it processed. When the semantic configuration of the negated concept only allows for one other state, readers can rapidly instantiate the single required state, as there are no other alternatives. When there are multiple possibilities, due to a more diffuse, scalar semantic ontology of the negated concept, readers interpret the negation less definitively.

A number of theoretical assertions have been made in this thesis, having used eye movement measures as an index of processing difficulty. As previously noted, previous models of negation have often been based on offline sentence rating or sentence picture verification tasks. Eye tracking measures are of a temporally high-resolution that reflect the cognitive processing (Liversedge & Findlay, 2000; Rayner, 1998; 2009) that occurred during the reading of negated passages. Eye movements are also a highly temporally sensitive measure, meaning they supply a specificity of

detail that cannot be reproduced in tasks, such as those above, that are often based on a readers' ultimate interpretation of the text. Furthermore, these tasks do not constitute normal reading; ensuring task effects will limit the validity of any findings regarding negation processing.

While previous accounts consider how negation is represented at the point it is interpreted, the data provided within this thesis provide an account for how definitive and ambiguous negated items are integrated into discourse during natural language processing. Furthermore, readers' eye movements, and therefore their cognitive processing of these items, were sensitive to this process. When negated items are bounded, they denote mutually exclusive states unambiguously. As such, readers are capable of rapidly interpreting the mutual exclusivity of multiple negated states. This is advantageous when these items are consistent, as readers can rapidly integrate this information. Conversely, when the information provided is inconsistent, readers struggle to overcome the logical contradiction, as there is no integrated state to represent. In the case of unbounded negation, besides the notion that it is represented more slowly, we found continued longer fixations and regressions back in text in regions after the target antonym. This presumably reflects ambiguity resolution processing required to incorporate this negation into the discourse representation. Not only do the results provide an account for the representation of negation, but extend our understanding in to the integration of negated concepts across passages of text.

Boundedness

The experiments detailed within this thesis expand our understanding of how readers process boundedness when reading. Previous experiments have found readers interpret bounded and unbounded items differently. This acted as motivation for the investigation of boundedness provided within this thesis. These previous experiments included similarity ratings, showing bounded negated items were seen as being more similar to their antonym than unbounded negated items (Fraenkel & Schul, 2008; Paradis & Willners, 2006). Furthermore, ratings of bounded negation have been found to occur within a more rapid time course than unbounded negation (Du et al., 2016; Mayo et al., 2004). The experiments within this thesis replicated the offline similarity ratings found in previous studies in English (Experiment 1b). The

current investigation of boundedness, however, was advanced even further by the exploration of negated concepts within passage contexts, where negated items could appear in opposition or complementary to one another. The results of Experiment 1c replicated the finding that bounded negation is interpreted as being more similar to its antonym than unbounded negation. A further finding, however, was that participants also considered two bounded negations to refer to very different states. In contrast, two unbounded were considered to be more similar, suggesting they are not necessarily interpreted as their antonym. This further suggested readers would be more able to integrate two unbounded negations into a conciliatory representation, as they both refer to a possible state (e.g. *not late* and *not early* could both refer to *on time*). In contrast, two bounded negations refer to mutually exclusive antonyms (e.g. *not dead* and *not alive* refer to the mutually exclusive states of *alive* and *dead* respectively. Ultimately, readers were sensitive to the linguistic variable of boundedness during similarity judgment tasks. Specifically, readers showed evidence of an appreciation for the categorical semantic configuration of bounded concepts, meaning bounded negation was interpreted as its antonym. In contrast, unbounded negation was interpreted more ambiguously, due to the more scalar semantic configuration of unbounded concepts.

In Experiment 2, it was found that boundedness could be appreciated during on-line language processing, not just within tasks that explicitly require comparison between ultimate interpretations of text. Readers were sensitive to the linguistic operator of boundedness, and it is a variable that is taken into account during on-line discourse representation formation. Despite the possible subtlety of a variable such as boundedness, readers were undoubtedly capable of making calculations about the semantic configuration of concepts as they were reading about them. Furthermore, readers rapidly detected logical contradictions that appear in text only as a result of the semantic ontology of the concept denoted. Anomaly detection effects were present when two bounded negations were presented within a single context. Anomaly detection indicated that readers did consider bounded concepts to only have two mutually exclusive and mutually exhaustive states, and make interpretations of the text accordingly. Conversely, two unbounded negations present a semantic ambiguity, where readers appear to show oculomotor behavior that would suggest a degree of inferential processing. Such processing is required in order to

differentiate between two unbounded negations and to disambiguate a logical state that could be denoted within the concept, which is outside of the two polar antonymic states.

Experiments 3 and 4 offered some insight into the processing of unbounded items, explaining how their ambiguity is handled during text comprehension. Both experiments provided results to suggest unbounded items provide less constraint than bounded items. In Experiment 3, connectives provided facilitation to reading comprehension. This occurred, however, with a later time course in the case of unbounded than bounded items. It has been suggested throughout this thesis that unbounded items supply less constraint to readers, meaning the continuity denoted to the reader does not allow them to limit their expectations of text. Bounded items, in contrast, supply much more by way of constraint over readers' representation of text meaning, allowing expectations to be more efficiently limited when supplied with a connective. As a result, bounded negation is more rapidly integrated into discourse when provided with a discourse marker. Finally, in Experiment 4, when presented with an unbounded negation in isolation, readers chose to underspecify their representation, presumably in the expectation that it would be disambiguated in later text.

In summary, this thesis offered several theoretical insights into the processing of boundedness. Specifically, readers are sensitive to the boundedness of negated elements when rating single sentences and passages, as well as during the on-line processing of passage texts. Furthermore, unbounded items appear to be processed in a manner befitting of the ambiguity they denote, due to the multiple states that exist within their semantic configuration. In comparison, bounded items appear to be appreciated as two mutually exclusive and mutually exhaustive states. As such, they are processed unambiguously, with more constraint applied to bounded mental representations.

Future Directions

While seemingly subtle, semantic configuration is a variable that must be considered within the majority of descriptive sentences uttered during language processing. The findings that readers show an on-line processing sensitivity to the semantic configuration of concepts denoted during communication motivates many

more questions about the semantic processing of concepts during language. As previously discussed, future research should investigate how coarse this sensitivity is. For instance, do readers differentiate between scalar and two-state concepts during online language processing? Are unbounded concepts considered more subjective or more abstract within situational models of text? There are many more investigations of boundedness that are still required in order to fully understand how readers accommodate semantic configuration during semantic processing of text.

Further research could also investigate the effects of modifiers on bounded and unbounded items. As bounded semantic configurations contain a categorical divide between the two, bounded adjectives appear resistant to the use of scalar degree modifiers, whereas unbounded adjectives do not (Paradis, 1997). For instance, *very dead* comes across as much less conventional than *very wide*, because *very* presupposes the use of a scale. Totality modifiers, such as *completely* or *almost* are said to presuppose categorical boundary. There have been corpus analyses, which support the notion that degree modifiers are used for unbounded items and totality modifiers are used for bounded items (Paradis, 2000, 2001, 2003). There is, however, very little empirical behavioural evidence to suggest readers recognize these uses of different types of modifiers. Furthermore, it would be interesting to see how modifier mismatches (e.g. *almost wide* or *somewhat dead)* are interpreted in offline ratings. For instance, is their use taken to suggest humour or ironic intent, in order to overcome their unconventional use? Further research could also investigate whether there is evidence to suggest readers show on-line detection of these mismatches between boundedness and modifiers.

Another relatively unexplored facet of negation processing is the effect of personality factors. Haran, Mor and Mayo (2014) have provided evidence to suggest individual difference is correlated with access to negated information. Specifically, participants who reported high levels of depressive rumination on self-referential information displayed a striking effect of markedness. In the case of non-contradictory items, participants that self reported high levels of depressive rumination appeared to interpret both negated positive and negative stems negatively. For instance, *not bad* was not interpreted as *good* but *not good* was interpreted as *bad*. The authors suggested that both phrases were interpreted in a more negative nature than participants who report much lower levels of depressive

rumination. Thus, it was suggested that negation processing is affected by personality factors, specifically; those who engage in depressive rumination do not interpret negated negative information as its antonym, but do interpret negated positive information as its antonym. Furthermore, Filik et al. (2017) suggested that readers who report high scores for indirect aggression are more likely to interpret negation as a sarcastic term. Not only is negation a pragmatically and contextually sensitive event, as the current boundedness study and many others demonstrate (Giora, 2006; Hasson & Glucksberg, 1999; Tian et al., 2010; Wason, 1965;) but it is also sensitive to individual difference. Furthermore, studies have also pointed towards the role of working memory in the speed of negation processing (Margolin, 2015; Margolin & Abrams, 2009). The role of individual difference in negation processing remains relatively unexplored experimentally and requires further research.

The influence of boundedness on negation interpretation using explicit negation (i.e. the word *not*) has been explored in Experiments 1-4. As a result, the nature of prefixal negation is outside of the scope of this thesis. There is evidence to suggest prefixal negation interacts with boundedness in a very different manner to explicit negation (Sherman, 1973). While explicit negation of a bounded antonym is interpreted as its antonym, it could be argued that prefixal negation is not. Consider the phrase *the room is not untidy*, while *tidy* is normally considered a bounded adjective, by placing it both within both an explicit negator and a prefixal negator's scope, it can be interpreted as unbounded (van der Wouden, 1996). Such a double negation is called a "litote", and it has been suggested that they are often used to express non-literal content, usually for the sake of humor. Non-literal meaning has an effect on the interpretation of bounded negation, but the manner of how remains unknown. Litotes, as well as much research on prefixal negation, has largely been investigated using offline sentence rating studies. Investigations of the online processing of these types of negation would advance our understanding of this particular part of language, especially with relevance to the effects of boundedness.

The findings within this thesis are the first to find boundedness affects on-line discourse comprehension. A differential processing of effect of boundedness was found through the use of an on-line index of cognitive processing during reading – eye tracking. Other on-line measures of processing could also offer insight into interpretation of boundedness. Event-related brain potentials (ERPs) have also been

shown to be a measure of high temporal acuity in conveying the time course for the semantic processing of text (Kutas & Fedemeier, 2011). For example, the N400 effect has been considered as an important index of semantic processing. Specifically, an enhanced centroparietally distributed, negative deflection that has an onset around 200 ms following word presentation, and peaks at about 400 ms after the critical word (Lau, Phillips & Poeppel, 2008). Larger N400 effects have been found for the reading of words that are semantically anomalous with their context or words that indicate a violation of world knowledge (Filik & Leuthold, 2008; Hald, Steenbeek-Planting & Hagoort, 2007; Leuthold, Filik, Murphy & Mackenzie, 2012; Nieuwland & van Berkum, 2006; Sanford, Leuthold, Bohan & Sanford, 2011; van Berkum, Zwitserlood, Hagoort & Brown, 2003;). The P600, a centroparietal late positive deflection 600 ms after word onset, also represents an important index for increases in discourse complexity or increased integration demands (Filik, Leuthold, Moxey & Sanford, 2011). While initially believed to be purely an index of syntactic violation (Hagoort, Brown & Osterhout, 1999), the P600 is now considered an important index for increased difficulty of integration (Burkhardt, 2007; Filik, Sanford & Leuthold, 2008; Kaan, Dallas & Barkley, 2007;).

With two effects known to be temporally sensitive indices of semantic anomaly and semantic integration difficulty, it is possible to make several predictions about the reading of bounded and unbounded sentences, if the interpretation of boundedness within this thesis is correct. First, consider the bounded incongruent condition, which resulted in readers immediately regressing out of the target region, without an increase in fixations. Readers were rapidly interpreting the mutual exclusivity between the two bounded states and detecting a logical contradiction. As readers can detect this logical contradiction so rapidly, an increased N400 should be expected for the reading of the second negation within these passages, similar to that found in semantic anomaly studies. Next consider the unbounded incongruent passages, where readers showed less severe reading delays reflected in eye movement measures. Less severe disruption was interpreted as being due to the lack of a logical contradiction, but also the need for inferential processing to disambiguate a possible state in between the two unbounded negations. Increased integration processing should yield an increased P600 effect, as found in studies showing this effect for increased integration demand. It is in this way that ERP measures could

provide further insight into the processing of boundedness. Finally, consider the difference between bounded and unbounded complementary passages, where the negation is only considered very similar to its antonym in the bounded case. As such, eye movement measures revealed very little reading disruption of the bounded complementary negation, unlike in the unbounded case. If the theoretical assertions made within this thesis are correct, it should be expected that only the unbounded complementary condition would yield an increased P600, reflecting the difficulty of integrating an unbounded negation with its antonym.

To further the point, concurrent investigations of eye tracking and EEG have provided unique contributions to our knowledge of semantic processing. For instance, Filik and Leuthold (2013) found readers were sensitive to events that did not match the typical behavior of a character in both ERPs and eye movements. Similarly, Ferguson, Sanford and Leuthold (2008) found a delay in the processing of counterfactual anomalies for eye movement and ERP measures. Finally, Filik, Leuthold, Wallington and Page (2014) found readers suffered delays in the reading of ironic statements, but only when they were unfamiliar. This effect was replicated in eye movement and ERP measures. Furthermore, recent advances suggest the co-registration of eye movements and ERPs may be of practical use in future research (Dimigen, Sommer, Hohlfeld, Jacobs & Kliegl, 2011; Henderson, Luke, Schmidt & Richards, 2013). Clearly, the use of both methodologies has made a significant contribution in the investigation of semantic processing during reading. Further investigation of boundedness, therefore, could benefit from the use of other temporally sensitive measures of cognitive processing.

In summary, the work within this thesis is the first to report a difference in processing of text, dependent on whether a negated element has a bounded or unbounded semantic configuration. Future research should attempt to further investigate this sensitivity shown by readers, through more subtle manipulations and through the use of other temporally sensitive measures of on-line cognitive processing.

Conclusion

The research presented in this thesis shows that there is a need to consider how readers encode semantic ontology during discourse comprehension. While it

could be considered subtle, boundedness pervades a large amount of language use, with most gradable adjectives and verbs possessing a semantic ontology that needs to be considered when used in language. Through the use of eye movement measures during natural reading, it has been possible to show that readers certainly are sensitive to boundedness during on-line language processing.

To summarize, from Experiments 1a-c, it was possible to conclude that readers can appreciate the difference between bounded and unbounded negation. Specifically, that bounded negation refers to its antonym, due to a lack of alternative states. In contrast, unbounded negation can refer to states other than its antonym, meaning it is possible to see more similarity between two unbounded negations than two bounded negations. In Experiment 2, it was found that participants continued to show a sensitivity to the variable boundedness in on-line measures of language comprehension. Bounded incongruent passages caused immediate and catastrophic delays to reading. Bounded complementary passages yielded very little reading delay, and were read similarly to repetition passages following the target. Both unbounded complementary and incongruent conditions caused disruption (compared to typical reading in the repetition conditions) that was quantitatively not as severe as the bounded incongruent passages. The key findings of this study were that readers are sensitive to boundedness and their oculomotor behaviour matched the theoretical predictions set up through the boundedness hypothesis (Paradis & Willners, 2006).

In Experiment 3, it was found that the time course of the facilitatory effect of a connective was modulated by boundedness. As unbounded items provide less constraint over a readers' expectations, there was a delay in the integrative facilitation in unbounded complementary passages. As such, bounded complementary passages showed shorter first fixation and gaze durations on the target, while unbounded complementary passages showed shorter go-past times and fewer regressions away from the target. This supports the notion that unbounded items are processed within a slower time course, and that unbounded items are inherently ambiguous, due to their subjective nature (Kennedy & McNally, 2005). In Experiment 4, it was found that negations appear to be left underspecified when presented in isolation. With the antonym order of the complementary condition reversed, there appeared to be no modulatory effect of boundedness in the reading of these passages.

This suggested that without disambiguating information, readers did not select a specific interpretation for unbounded negation, due to the range of possibilities.

The experiments within this thesis have provided a novel approach to understanding how people comprehend negation and boundedness during reading. They were motivated by theories of negation and boundedness, with clear theoretical motivation for the experimental designs employed. Rigorous offline testing and analysis of eye movement patterns in the reading of bounded and unbounded negation has provided vital information in understanding how this complex process occurs during reading. With these findings established, the foundations for future research into these variables has been provided.

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Appendix A: Materials from Experiment 1A

Unbounded Stimuli:

It was good/bad news.

He was a loud/quiet person.

His condition had improved/deteriorated.

The response was slow/fast

He had been shouting/whispering.

The economy had contracted/expanded.

His height was his strength/weakness.

The feelings were of shame/pride.

The way they played was rough/gentle.

The soldier was a hero/coward.

The couple argued violently/gently.

The son reacted happily/sadly.

The tomatoes were layered thickly/thinly.

The collision was serious/minor.

The question was intelligent/stupid.

The colour was dark/light.

The water was clean/dirty.

This work was his worst/best.

The oranges were sour/sweet.

The figures were low/high.

The level was higher/lower.

The grass was long/short.

The tone was sad/happy.

The child was happier/sadder.

The coffee was cold/hot.

The weather was getting hotter/colder.

The dress was old/new.

The package was heavy/light.

The instructions were vague/clear.

The exercise was easy/hard.

The glass was empty/full.

The pool was shallow/deep.

The road was wide/narrow.

The employee arrived late/early.

Bounded stimuli:

The battle ended in victory/defeat.

The story was the/a truth/lie.

He was a success/failure.

He failed/passed the inspection.

The boxer was victorious/defeated.

The man was a sceptic/believer.

The painting was a/n original/copy.

The proposal was a demand/request.

The man was a leader/follower.

The man was a guest/host.

The country was in conflict/at peace.

The singer was female/male.

His identity was shown/hidden.

The defendant would deny/admit the charge.

The offer was accepted/rejected.

The border was closed/opened.

The patient survived/died (in/through) the night.

His swing hit/missed the ball.

The car would fail/pass the MOT.

They had operated illegally/legally.

He was hurt intentionally/accidentally.

The events were fantasy/reality.

The alibi was true/false.

The bridge was dangerous/safe.

The knife was sharp/blunt.

The barstool was taken/free.

The bone was intact/broken.

The clothes were wet/dry.

The fireman was certain/doubtful.

The damage was accidental/intentional.

The schoolgirl was absent/present.

The defendant was innocent/guilty.

The room was tidy/messy.

The door was closed/open.

The patient was alive/dead.

The hostages were free/captive.

Appendix B: Materials from Experiment 1B

Bounded Items

The patient was dead. The patient was not alive.

The patient was alive. The patient was not dead.

The agent's identity was shown. The agent's identity was not hidden.

The agent's identity was hidden. The agent's identity was not shown.

His actions were a success. His actions were not a failure.

His actions were a failure. His actions were not a success.

The boxer had won the match. The boxer had not lost the match.

The boxer had lost the match. The boxer had not won the match.

The collision was serious. The collision was not minor.

The collision was minor. The collision was not serious.

The alibi was true. The alibi was not false.

The alibi was false. The alibi was not true.

The damage was accidental. The damage was not intentional.

The damage was intentional. The damage was not accidental.

He hurt her intentionally. He hurt her accidentally.

He hurt her accidentally. He hurt her intentionally.

The clothes were wet. The clothes were not dry.

The clothes were dry. The clothes were not wet.

The bone was broken. The bone was not intact.

The bone was intact. The bone was not broken.

The door was open. The door was not closed.

The door was closed. The door was not open.

The room was tidy. The room was not messy.

The room was messy. The room was not tidy.

The scalpel was sharp. The scalpel was not blunt.

The scalpel was blunt. The scalpel was not sharp.

The bridge was safe. The bridge was not dangerous.

The bridge was dangerous. The bridge was not safe.

The loggers had operated legally. The loggers had not operated illegally.

The loggers had operated illegally. The loggers had not operated legally.

The baby was awake. The baby was not asleep.

The baby was asleep. The baby was not awake.

The defendant was innocent. The defendant was not guilty.

The defendant was guilty. The defendant was not innocent.

The story was the truth. The story was not a lie.

The story was a lie. The story was not the truth.

The events were fantasy. The events were not reality.

The events were reality. The events were not fantasy.

The MOT did pass. The MOT did not fail.

The MOT did fail. The MOT did not pass.

The swing at the ball had missed. The swing at the ball had not hit.

The swing at the ball had hit. The swing at the ball had not missed.

The pupil was present. The pupil was not absent.

The pupil was absent. The pupil was not present.

The patient had died. The patient had not survived.

The patient had survived. The patient had not died.

The border checkpoint was closed. The border checkpoint was not opened.

The border checkpoint was opened. The border checkpoint was not closed.

The criminal charges were admitted. The criminal charges were not denied.

The criminal charges were denied. The criminal charges were not admitted.

The offer was accepted. The offer was not rejected.

The offer was declined. The offer was not rejected.

The singer was a male. The singer was not a female.

The singer was a female. The singer was not a male.

The instructions were clear. The instructions were not vague.

The instructions were vague. The instructions were not clear.

The restaurant passed the inspection. The restaurant had not failed the inspection.

The restaurant failed the inspection. The restaurant did not pass the inspection.

The man was an atheist. The man was not religious.

The man was religious. The man was not an atheist.

The oil painting was an original. The oil painting was not a copy.

The oil painting was a copy. The oil painting was not an original.

The team member was a leader. The team member was not a follower.

The team member was a follower. The team member was not a leader.
The man was a guest. The man was not a host.
The man was a host. The man was not a guest.
The country was at war. The country was not at peace.
The country was at peace. The country was not at war.
In battle they were defeated. In battle they were not victorious.
In battle they were victorious. In battle they were not defeated.
The hostages were free. The hostages were not captive.
The hostages were captive. The hostages were not free.

Unbounded Items

The employee was late. The employee was not early.
The employee was early. The employee was not late.
The response was fast. The response was not slow.
The response was slow. The response was not fast.
The color was dark. The colour was not light.
The colour was light. The colour was not dark.
The water was clean. The water was not dirty.
The water was dirty. The water was not clean.
The work was his best. The work was not his worst
The work was his worst. The work was not his best.
The runner had come first. The runner had not come last.
The runner had come last. The runner had not come first.
The orange was sour. The orange was not sweet.
The orange was sweet. The orange was not sour.
The sales figures were low. The sales figures were not high.
The sales figures were high. The sales figures were not low.
The grass was long. The grass was not short.
The grass was short. The grass was not long.
The novel's tone was happy. The novel's tone was not sad.
The novel's tone was sad. The novel's tone was not happy.
The child was happier. The child was not sadder.
The child was sadder. The child was not happier.

The coffee was hot. The coffee was not cold.

The coffee was cold. The coffee was not hot.

The weather was hotter. The weather was not colder.

The weather was colder. The weather was not hotter.

The schoolboy had been shouting. The schoolboy had not been whispering.

The schoolboy had been whispering. The schoolboy had not been shouting.

The dress was old. The dress was not new.

The dress was new. The dress was not old.

The package was light. The package was not heavy.

The package was heavy. The package was not light.

The exercise was easy. The exercise was not hard.

The exercise was hard. The exercise was not easy.

The pool was shallow. The pool was not deep.

The pool was deep. The pool was not shallow.

The road was wide. The road was not narrow.

The road was narrow. The road was not wide.

The proposal was a request. The proposal was not a demand.

The proposal was a demand. The proposal was not a request.

The colleague was loud. The colleague was not quiet.

The colleague was quiet. The colleague was not loud

The way the children played was rough. The way the children played was not gentle.

The way the children played was gentle. The way the children played was not rough.

It was good news. It was not bad news.

It was bad news. It was not good news.

His condition did improve. His condition did not deteriorate.

His condition did deteriorate. His condition did not improve.

They did argue aggressively. They did not argue calmly.

They did argue calmly. They did not argue aggressively.

The sliced tomatoes were thinly layered. The sliced tomatoes were not thickly layered.

The sliced tomatoes were thickly layered. The sliced tomatoes were not thinly layered.

The boy would react happily. The boy would not react sadly.

The boy would react sadly. The boy would not react happily.

The water level was lower. The water level was not higher.

The water level was higher. The water level was not lower.
The glass was empty. The glass was not full.
The glass was full. The glass was not empty.
The economy had expanded. The economy had not contracted.
The feelings were of shame. The feelings were not of pride.
The feelings were of pride. The feelings were not of shame.
The soldier was brave. The soldier was not cowardly.
The soldier was cowardly. The soldier was not brave.
His height was a weakness. His height was not a strength.
His height was a strength. His height was not a weakness.
The question was intelligent. The question was not stupid.
The question was stupid. The question was not intelligent.

Unrelated Items

The kettle was boiling. The kettle was not rusting.
The kettle was rusting. The kettle was not boiling.
The coins were made of gold. The coins were not payment.
The coins were payment. The coins were not made of gold.
The act was a trap. The act was not entertainment.
The act was entertainment. The act was not a trap.
The tramp was limping. The tramp was not yelling.
The tramp was yelling. The tramp was not limping.
The weather was sunny. The weather was not forecastable.
The weather was forecastable. The weather was not sunny.
The fruit was ripe. The fruit was not seedless.
The fruit was seedless. The fruit was not ripe.
The sinner was repentant. The sinner was not muddy.
The sinner was muddy. The sinner was not repentant.
The anchor was damp. The anchor was not large.
The anchor was large. The anchor was not damp.
The athlete was running. The athlete was not washing.
The athlete was not washing. The athlete was not running.
The creature was a lizard. The creature was not food.

The creature was food. The creature was not a lizard.

The house was made of wood. The house was not a home.

The house was a home. The house was not made of wood.

The sportsman was tired. The sportsman was not worried.

The sportsman was worried. The sportsman was not tired.

Appendix C: Materials from Experiment 2

Bounded Passages

1. *Rushing into the emergency room, the doctor and nurse were talking about one of their cases. The Doctor stated clearly that the patient was not dead/alive. The nurse declared that the patient was not dead/alive and noted it down in her paperwork. Great care was taken to regularly check the condition of all the patients.*
2. *The wedding reception was getting underway. Following several requests, the guest complained loudly that the door was still not open/closed. The hotel proprietor said the door was not closed/open and repositioned the door for the guest. Everyone thought that the host was very professional and conducted himself politely.*
3. *A mother and her friend were surveying the family room. The mother, who was somewhat authoritative, said that the family room was not messy/tidy. Without any hesitation, her friend said that the family was not tidy/messy by her standards. The family room was often used to watch television and chat.*
4. *It was Friday evening and the couple were getting ready to watch television. The husband told his wife that he had checked the young baby in bed and she was not asleep/awake. Just to be certain, the wife went upstairs to confirm. She saw that baby was not asleep/awake but still worried about her child. It was quire understandable that the new parents would worry.*
5. *The court was packed and everyone listen intently to the proceedings. The head juror announced that the jury believed that defendant was not innocent/guilty. Upon hearing this, the judge banged his gavel and found the accused to be not guilty/innocent of the alleged crime. There was an outcry in the public gallery and many people were emotional.*
6. *The children filed into the classroom and sat at their desks. Almost immediately, Jane noticed that her friend, Tracey was not absent/present. The teacher then started to take the register calling out each pupil's name in turn. The teacher marked Tracey as not present/absent for that day. The children were well behaved and silent during registration.*
7. *The case was very intricate and the evidence was complex. The police inspector who had been investigating stated categorically that the criminal's alibi was not true/false. Also, a witness to the crime had testified that the alibi was not true/false from what*

they saw. The Police Chief needed to solve the crime soon as the public wanted an arrest.

8. *It was clear that the damage to the car was extensive and it would cost a lot of money to get it fixed. The owner maintained that the damage caused was not accidental/intentional. The policeman who has come to the incident recorded in his notes that the damage was not accidental/intentional, and then he headed back to the station to file his report. The paperwork associated with the job was a real bind.*
9. *The detective had finally managed to pull in a suspect for the recent robbery for questioning. The defendant said that she had not falsely/truthfully answered the question. The detective accepted that the defendant had not falsely/truthfully answered when asked were she was on the night of the robbery. It looked as though he would spend a few mote nights solving the crime.*
10. *The wealthy man had hired members of staff to maintain his household affairs, including a cleaner to do his laundry. The cleaner mentioned repeatedly that the client's washing was not wet/dry. When she was asked, the maid said that the client's clothes were not wet/dry on the line. The client needed his laundry to be ready for his forthcoming trip.*
11. *Jane was going to hospital after being hurt in a car crash. She was absolutely certain that her leg bone was not intact/broken. The driver of the car examined her leg and declared it was not intact/broken from the accident. The car crash had been a particularly scary experience.*
12. *The parents of the schoolboy had arrived at school for parents evening. The boy had gone on for days about the fact that he was not passing/failing English. The English teacher agreed that the boy was not passing/failing English so far this year. The English teacher would have to speak to many more parents before the evening would end.*
13. *The surgeon was checking his sterile instruments in readiness for the forthcoming operation. He was insisting that the medical scalpel was not sharp/blunt. It was clear that the knife as not sharp/blunt as the surgeon cut into the skin. For a successful procedure, the operation required a general anaesthetic.*
14. *The explorer was being taken to the remote settlement for the first time with a guide. He forcefully made clear his opinion that the jungle bridge was not safe/dangerous. It*

was the assessment of the guide that the bridge was not safe/dangerous for them to cross. Accessing the village was only possible via the bridge.

15. *The capture of the US hostages had caused a political storm. The newspaper reports carried quotes that the hostages were not free/captive. The US President had been advised that the hostages were not captive/free before entering into diplomatic talks with the rival nation. It was the policy of the US that they would not negotiate with terrorists.*
16. *The children complained that they were not tired, even though it was very late. The babysitter told the children a bedtime story, and told them that the events were not fantasy/reality. The children were convinced that the events of the bedtime story they heard were not fantasy/reality, as they listened to the story tiredly. Eventually, after some time, the children went to sleep.*
17. *The child's parents had been asked to visit the headmaster after another pupil had hurt their daughter at lunch. The parent thought that other pupil did not accidentally/intentionally hurt her daughter. The teacher had seen that the pupil did not accidentally/intentionally hurt the girl while they were playing. It appears that the incident had occurred during the lunch break.*
18. *Deforestation of the rainforest had forced the government to investigate the logging company. The latest investigation said that the loggers had not legally/illegally operating. A second, follow-up investigation found that the loggers had not legally/illegally operated in the forests. Deforestation is harmful to the environment when it is not done in a sustainable manner.*
19. *The car has been brought into the garage, as it was time for the year's MOT. Two mechanics, John and Steve worked on the car together. During the MOT test, John knew that the car would not pass/fail. Steve finished working on the car and decided to not pass/fail the car's MOT. An MOT certificate was necessary to ensure a car is roadworthy.*
20. *At the baseball match, the umpire had just made a decision regarding the batter's last swing. The umpire declared that the batter's swing at the ball had not hit/missed. The scoreboard showed that the batter had not hit/missed the last ball. Replays were shown of the better's swing on television.*
21. *A Doctor and a Nurse had just finished examining the patient. The Doctor told the Nurse that, in the night, the sick patient had not survived/died. The Nurse informed the*

patient's family that the patient had not survived/died in the night. No one expected the patient to make a recovery.

22. *Following an uprising in the neighbouring country, politicians made a decision on who could cross the borders. The news said that border control had ensured that the border checkpoint was not opened/closed. The refugees saw the border checkpoint was not opened/closed when they approached them. Immigration is an issue many people feel strongly about.*
23. *The entrepreneur had received a sizable bid from a rival to sell the company he had started several years ago. Workers at the company knew that the offer was not accepted/declined. The entrepreneur told the rival company he had not accepted/declined the offer presented to him. It had taken years to build up his company, which increased its value.*
24. *The suspect had been given a comprehensive description of his charges and the evidence supporting them. Because of the evidence they had, the chief investigator knew the defendant would reply to the charge and would not accept/deny them. The accused suspect decided that he would not deny/accept the criminal charges. It had taken months to build some sort of case against the suspect.*
25. *Footage showing the mysterious secret agent had been captured on film and sent to various new outlets. The BBC commissioner said that it was in the public interest that the agent's identity would not be hidden/shown. On the BBC evening news that night, the identity of the secret agent was not shown/hidden during the news story. The secret agent had been on an assignment relating to national security.*
26. *Marie and Alex went to see the band with the androgynous singer. Alex thought the lead singer of the band was not male/female. Marie judged that the leader of the band was not male/female by the second song. The heavy make-up made it very hard to judge.*
27. *The corporal was to make a public announcement regarding the result of the latest battle. The corporal announced that the long battle was not a victory/defeat. It was broadcast in the news as coverage of a battle that was considered not a victory/defeat for their nation. The corporal was known for his unusual warfare tactics.*
28. *The diplomats were preparing to fly to a country ravaged by civil war. The news coverage displayed that the poor country was at peace/in conflict. Upon arrival, the diplomats put out a public statement that the country was not in conflict/at peace and*

were trying to talk to the government of the country. The diplomats were hoping to avoid any future conflict.

29. *The businessman was attending a party for charity following an invitation to his company. Upon arrival, it was his understanding that the distinguished-looking man was not a guest/host. Other attendees thought that the man was not a guest/host of the high profile event. Everyone still anted to talk to the man regardless.*
30. *The applicants had to work in teams during the group interview. During one of the management assessments, the supervisors judged that one of the applicants was not a leader/follower. The applicant's feedback reflected that he was not a followed/leader within the group. To join the company, applicants underwent many rigorous assessments.*
31. *The trade union and factory bosses met to try and end the strike. When the trade union suggests wage improvements, it was a request/demand. The factory bosses clearly understood that the proposal was not a request/demand from the unionists. The unionists were seeking a wage increase that was equal to inflation.*
32. *The collector was attending an art auction with the intention of buying a new painting. He assumed that the first lot for sale, a fine oil painting, was not a copy/an original. He took advice from a fellow collector, who believed that the Monet piece was not an original/copied piece of his work. The auctioneer as pleased with the price that the painting fetched.*
33. *The priest and a man from his parish were having a theological discussion about faith, as they often would whenever they spoke to each other. During their discussion, the priest brought up that the man was not an atheist/religious person. The accused man happily admitted that he was not a religious/atheist person at all. The man's faith was a topic he was open about.*
34. *The accountant was meeting with one of his clients to discuss some of the latest investments. The account knew that his latest actions were a success/failure. His client thought the investments were not a success/failure given the state of the economy. The accountant depended on strong performance in the marked for his reputation.*
35. *The owner of the restaurant had been thinking about the outcome of a recent health inspection. He had heard one of the inspectors say that his restaurant had not passed/failed the inspection. When the report from the inspectors arrived, it indicated*

that the restaurant had not passed/failed this year's health inspection. It is very important to have a clean kitchen when making food for lots of customers.

36. *The headmaster was trying to work out whether one of his students was telling the truth about how the fight in the playground had started. One girl he asked was adamant that the student's story was not a lie/the truth. The boy that he asked next had been standing with the girl and had also watched the events on the playground unfold. The boy said that the student's story was not a lie/the truth about how the events actually occurred. The headmaster was determined to get to the bottom of what had happened.*

Unbounded Passages

1. *The boss was checking his new employee's attendance record with his secretary. The boss was quite clear that the new employee was not early/late. Following her orders, the secretary noted in her records that the employee was not early/late for work today. It was the secretary's job to maintain employee records.*
2. *The two men in the lorry turned left into a busy road. While they were in conversation, the driver of the lorry mentioned that the busy road was not narrow/wide. Slightly later in the journey, the passenger commented that the road was not narrow/wide as they continued. In the mornings, the road was always particularly busy.*
3. *The swimmer was trying out the new pool for the first time. He loudly told the lifeguard that the pool was not shallow/deep. The lifeguard had already noticed that the pool was not shallow/deep when he first came on duty. The sports centre had received a government grant to build a new pool.*
4. *The customer in the bar had just received his first drink of the night from the barman. Looking at his drink, the customer causally mentioned that the pint glass was not empty/full. The barman replied that the glass was not empty/full while pouring a drink for someone else. The bar became crowded very quickly as people arrived after work.*
5. *Following a lesson on trigonometry, the teacher has set the class some homework exercises. Before handing his work in, one student told that teacher*

that the maths exercise was not easy/hard. The teacher responded that the exercise was not easy/hard, based on his experience. The teacher prided himself in being able to explain complex problems clearly to the students.

6. *The boss was walking around the office checking on his employees. Eh asked one employee about his progression on a set task. The employee included in his update that the task instructions he had been given were not vague/clear. It was the boss' opinion that the instructions were not vague/clear when he considered the situation. Improving efficiency of the manufacturing process was the boss' priority.*
7. *The postman had been given a package to deliver. Having been in the job for many years, the postman said that the package was not heavy/light. The post office weight classification label indicated that it was not a light/heavy package for delivery. Health and safety legislation requires that the weight of packages should be clearly and accurately marked.*
8. *Once again, alive has asked her best friends to help her get ready for a party. Alice said that the dress she was wearing tonight was not new/old. Her friends were all certain that dress was not an old/new item of clothing. They had all spent hours getting ready for tonight.*
9. *The weather had not been a pint of discussion lately. Everyone in the area knew that the weather was not colder/hotter. In his report. The weatherman stated explicitly that the weather was not colder/hotter over the last week. The weatherman was still relatively new in his job.*
10. *In a coffee shop, the waiter delivered a coffee to the woman's table. When he picked up the cup, he noticed that the coffee was not hot/cold. The customer remarked that the coffee was not hot/cold when she tasted it. She usually went to the coffee shop over the road.*
11. *The child had been receiving emotional counselling for a few months. The counsellor argued that child was not happier/sadder than before therapy. After the course of therapy, the parents felt that the child was not happier/sadder than before the sessions began. The counsellor specialised in work relating to children.*
12. *The author was attending a press conference to speak about his new novel when he was asked; the author said that the tone of his latest novel was not happy/sad.*

The reviews in the media very clearly stated that the book was not happy/sad in its tone. The author had taken many years to work on the latest book.

13. *The Lord of the manor was inspecting his ground with a member of his workforce. He immediately noticed that the grass on the lawn was not long/short. His gardener replied that he thought that the grass was not long/short for this time of year. The gardener's job was to keep the garden well maintained.*
14. *Two scientists in the oceanography lab were discussing their findings about sea levels. Compared to last year, the first oceanographer's data showed that the sea's average water level was not higher/lower. His colleague claimed, from the results from his experiments, that the water level was not higher/lower than last year. They had bother devoted their careers to investigating climate change.*
15. *Oliver was entering a routine monthly meeting with his boss to discuss targets. Going into the meeting, he thought that his sales figures for the month were not high/low. His boss told him unequivocally that his figures were not high/low for the year. The sales targets were based on the whole team's average performance.*
16. *At the expensive restaurant, several of the customers were discussing the new dessert. One diner noted openly that she felt the dessert oranges were not sweet/sour. On a different table, another customer judged that the oranges were not sweet/sour in any way. The dessert chef at the restaurant was world-renowned.*
17. *After 26 gruelling miles, the runner had just crossed the finish line. The announcer declared that the runner's placing was not first/last in the marathon. The crowd at the finishing line witnessed that the runner's placing was not first/last in this race. The weather had been kind and it had been a lovely day for the race.*
18. *The famous artist was thinking about his new collection of works. He had read a critique stating that this work was not his worst/best. The artist knew that his current work was not the best/worst of his career. An exhibition based on the new collection opened to the public next week.*
19. *The married couple were doing the washing up together. While drying a plate, the wife pointed out that the washing up water was not clean/dirty. Her husband could see that the water he was using to wash the dishes was not clean/dirty in*

any way. The couple would often do the washing up together and sometimes argue.

20. *The family were viewing a new house with the possibility of purchasing it. The mother realised immediately, upon entering her son's potential bedroom, that the colour of the walls was not light/dark. Her teenage son wished to change the colour, as it was not light/dark enough for him. Some redecoration would clearly be needed if they decided to buy the house.*
21. *A student had asked a question at the end of the lecture. The lecturer clearly thought that the question was not clever/stupid. Most of the audience held the opinion it was not a stupid/clever question to ask. The lecturer always had to be ready to answer unexpected questions.*
22. *The police were trying to obtain an account of the incident on the busy road. The driver claimed that the collision was not serious/minor. The pedestrian onlooker said that the collision was not serious/minor and occurred in the high street. Following the incident, the police closed the road, which annoyed many motorists.*
23. *The judges had made a clear decision over the result of the boxing match. Once the fight finished, the judges decided that the boxer was not defeated by/victorious over his opponent. The heavyweight boxer accepted that he was not victorious/defeated in the fight. The media coverage of the fight was global.*
24. *The chef was trying to remember how to make a difficult dish. The chef thought the recipe worked best with sliced tomatoes that are not thickly/thinly layered in the dish. His teacher had taught him that the recipe worked with tomatoes that are not thinly/thickly layered before cooking. The tomatoes also needed to be as fresh as possible.*
25. *The parents were discussing the impact that having another baby would have on their son. The mother could tell that if they told their son they were having another baby, his reaction would not be of happiness/sadness. As he went to tell him, the father judged that his son's reaction would not be of happiness/sadness when confronted with the news of a new sibling. The couple had been trying for another baby for months.*
26. *In the office of the marriage counsellor, the couple were discussing their latest argument. The husband claimed they did not gently/violently argue. The wife's*

account said that they did not gently/violently argue during their last disagreement. The counsellor encouraged the couple to learn to compromise.

27. *Two army officers were discussing the actions of one of their soldiers. The sergeant's view of the soldier was that he was not cowardly/brave based on the recent incident. The captain felt that the soldier was not cowardly/brave based in his actions. The outcome of their discussion would have implications for the soldier's career progression.*
28. *During a reunion, a group of soldiers discussed their actions together during the war. The veteran revealed that the feeling he felt was not pride/shame. Some of the other platoon members admitted their feelings were not of pride/shame when they reflected on their actions. It is quite common for veterans to spend time ruminating on their past experiences.*
29. *Before the event, the sportsman needed to assess his next opponent. The sportsman knew that his opponent's height was not a strength/weakness. The opponent's coach was aware that the sportsman's height was not a strength/weakness in their match. Sportsmen analyse their opponent's attributes to gain an advantage.*
30. *The National Bank recently released figures relating to the economy this last year. The president strongly believed that the country's economy had expanded/contracted. His financial advisors judged that the economy had not expanded/contracted in the last financial year. Political commentators heavily debated the state of the economy.*
31. *The headmaster was deciding whether to punish the schoolboy. The schoolboy said that he was not shouting/whispering in class. A classmate admitted that the boy was not shouting/whispering throughout the maths lesson. Talking during lessons is disruptive for the other pupils.*
32. *Following the accident, the victim was waiting for the emergency services. She thought that the emergency response was not slow/fast. On arrival, the medic told the victim that their response had not been fast/slow on this occasion. Medics must remain calm in various high-pressure environments.*
33. *A medical team was assessing the effect of an experimental procedure. The doctor's professional diagnosis was the since the procedure, the patient's condition had not improved/deteriorated. The radiologist looked at the same*

medical assessments and claimed that the patient's condition had not deteriorated/improved since the beginning of treatment. The efficacy of the experimental procedure was under significant scrutiny.

34. *A new employee, Alex, had just joined the office, sparking plenty of gossip among the other workers. While on a lunch break, one worker noticed that Alex was not a loud/quiet person. Some others around the office said, after conversations with the worker, that he was not a loud/quiet person around the office. Given some time, the new employee would settle in.*
35. *The mother sat down her two children, a son and a daughter, to tell them about what had happened at work. Once she had finished, her son's instant reaction was that it was not good/bad news. Before he could say anything, the daughter gave her opinion that it was not good/bad news for the family. Since their father had left, the mother tried to be very open with her children.*
36. *A teacher was supervising the children in the background during their lunch break. While the children played, the teacher commented to herself that the way the children played was not rough/gentle. A passer-by walked past the school and saw the children playing. The passer-by thought that the way the children played was not gentle/rough as she walked past the school. It's always difficult to predict how different children will get along.*