NEGATION PROCESSING

A DYNAMIC PRAGMATIC ACCOUNT

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Declaration

I, Ye Tian, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Acknowledgements

Abstract

This thesis investigates the processing of negative assertions. Psycholinguistic research shows that out-of-context negative sentences are more difficult to process than positive sentences. In the early stages of negation processing, the positive counterpart is often represented. Pragmatic research shows that negative sentences have richer pragmatic functions than positive sentences. These findings require a theory of negative sentence processing that can account for both the processing effects and pragmatic functions. Among current theories, a popular approach – rejection approach – attributes the processing effects to the processing of the linguistically coded meaning of negative sentences. They propose that negative sentences are represented as the rejection of their positive counterparts. They state that the representation of the positive counterpart is a mandatory first step of negation processing, and explain the processing cost in terms of the extra step of embedding.

Arguing against current theories (especially rejection accounts), I propose the dynamic pragmatic account. In general, sentence processing – with or without explicit context- should not only involve processing the linguistically coded content, but also involve inferring pragmatically retrieved content such as how the sentence relates to the broader discourse. Specifically, when we interpret an assertion, we not only process the asserted meaning, but also the Question Under Discussion (QUD) addressed by this assertion, which can be retrieved and accommodated using linguistic and non-linguistic cues. Negation is a cue for retrieving the prominent QUD. Without contextual support or further cues, the most prominent QUD for a negative sentence $\neg p$ is the positive question *whether p*. The projection of this positive QUD is due to the most frequent uses of negation, and is sensitive to other factors (e.g. frequency of the predicate and context) and other QUD cues (e.g. prosodic focus and cleft construction). I propose that the accommodation of a positive QUD contributes to the processing cost of negation, explains why the positive counterparts are often represented, and accounts for the pragmatic effects of negative sentences.

The dynamic pragmatic account and competing theories are tested in three series of experiments in Chapters 3-5. In Chapter 3, I show that the representation of the positive counterpart is not a mandatory first step for negation processing. Rather it is likely due to QUD accommodation. When a negative sentence projects a negative prominent QUD (such as a cleft negative sentence "It is John who hasn't ironed his shirt"), the positive counterpart is no longer represented. In Chapter 4, I investigate the verification of negative sentences against pictures. Previous studies have reported inconsistent results where verifying true negative sentences can take less, equal amount or more time than verifying false negatives. I argue that two strategies can be used in the task: the default strategy and the truth-functional strategy. The default strategy is to infer and represent the situation that makes the sentence true and compare it with the evidence. In addition, the accommodation of the positive QUD may encourage the development of a truth-functional strategy, in which participants answer the positive QUD and then switch the truth index. I show that when negative sentences project positive QUDs, there is a training effect: the reaction time pattern of true and false negatives change over time, indicating a development of a task-specific strategy; on the other hand, when negative sentences project negative QUDs, participants no longer develop the task-specific strategy. In Chapter 5, I investigate the time course of negative sentence processing in a visual world eye-tracking study. The results show that processing simple negative sentences is delayed compared to processing simple positives, but processing cleft negatives is no more delayed than processing cleft positives. Importantly, both QUD accommodation and the integration of the meaning of negation can happen incrementally. Overall, the findings speak against current models of negation processing (especially rejection accounts), and support the dynamic pragmatic account.

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Introduction

This thesis concerns the processing of negative utterances. Negation is a universal phenomenon in human languages. All natural languages have negation, yet it seems to be absent in all other animal communication systems (S Altmann, 1967). We use negation frequently for a wide range of purposes, including rejection, denial and talking about non-existence. According to the Oxford English Corpus, "not" is the 13th most frequently used word in the English language. If we look at the combined frequency of "not" and "no", negation is in the top 10 list. Negation enables us to entertain the truth value of a proposition, which is one of the central aspects of language use (Kant, 1787). Without negation, we would be without logic or even modern science.

Research on negation presents two asymmetries: (1) the high frequency of negation in natural language and the reported processing difficulty and (2) the simple semantic function of negation and its rich pragmatic effects. The first asymmetry lies between the high frequency of negation and its reported requirement in processing effort. Frequency greatly influences processing effort. Research shows that frequent words are recognized faster, understood faster and acquired earlier (see discussion by Ellis, 2002). Although we use negation frequently and rather effortlessly (at least according to our intuition), numerous psycholinguistic studies reported that negative sentences are more difficult to process than positive ones. Participants take longer to comprehend negative sentences, struggle to evaluate whether a negative sentence is true or false, to reason when negation is involved, or to remember information contained in a negative sentence. In addition to being difficult, negative sentences

seem to have a very close relationship with their positive counterparts. Many studies show that when we process a negative sentence, such as "the shop is not open", we often first process and represent its positive counterpart "the shop is open". These findings lead to my first set of questions:

Question 1a: why are negative sentences difficult to process (at least in psycholinguistic experiments)?

Question 1b: why is the representation of the positive counterpart often involved?

The second asymmetry lies between the simple semantic meaning of negation and its rich pragmatic effects (Horn, 1989). In classical logic, negation is a one-place truth-functional connective. If a proposition p is true, then the negation of p is false, and vice versa. By this analysis, propositions p and $\neg p$ differ only in their truth values, and p and $\neg\neg p$ are semantically equivalent. However, in natural language use, a doubly negated sentence often doesn't convey the same meaning as the sentence in positive form. For example, "I am not unhappy" seems to convey a different meaning from "I am happy". Also, a negative sentence does not just communicate the opposite of a positive sentence. Consider this example. There are streets in London with many small hotels. When you walk along such a street, you will see many hotel signs. If among these houses, you see a sign which says "this is not a hotel", what will you think? This sign seems superfluous. We don't put up signs to say what the house is *not*, as the list would have to be infinitely long. Upon seeing this sign, you do not just understand that the house is not a hotel, you also infer that many people have asked if it was a hotel or have mistaken it as one. The sign is for

people with such a query or assumption. This pragmatic effect raises the second question:

Question 2: how does negation allow us to infer such background information?

This thesis investigates these two questions plus a further one: how are questions 1 and 2 related?

Here is a roadmap for the thesis: in Chapter 1, I review psycholinguistic findings and current theories on the processing of negative sentences. Many studies tested the processing of negative sentences without context and some tested negative sentences in discourse context. When negative sentences are processed without context, two main effects were found: (1) negation requires extra processing effort, and (2) in the early stages of negation processing, participants often represent the positive counterpart. When negative sentences are processed with a supporting context, both effects diminish: negative sentences are almost as easy to process as positive ones, and the positive counterpart is no longer represented. Current accounts of negation processing come from three perspectives: grammatical, rejection-based and contextual. The dominant rejection-based approach (e.g. Carpenter & Just, 1975; Kaup, Zwaan, & Lüdtke, 2007) suggests that that negation is difficult *because* we must first process and represent the positive argument of negation and then reject it. Negative sentences take longer to process because of the extra step of embedding. However, no current account is consistent with all the empirical findings.

In Chapter 2, I propose the dynamic pragmatic account of negation processing. Following the dynamic semantic and pragmatic approach to meaning, this account

views context as an integral part of sentence interpretation, whether or not an explicit context is provided. I first set up the scene by comparing language use to a game where participants interact according to rules to achieve goals. I discuss what context is and how it interacts with utterance interpretation. Against this scene, I introduce the idea of Question Under Discussion and its accommodation, which are the backbone of my account. The main idea is that negation triggers a contextual accommodation. I will survey linguistic examples and corpus findings and evaluate them against my account, and then make predictions regarding the online processing of negative sentences.

Chapters 3 to 5 present three series of experiments testing current accounts of negation processing and the dynamic pragmatic account. Chapter 3 investigates whether the representation of the positive counterpart is a mandatory first step of negation processing, as suggested by rejection accounts. Chapter 4 discusses the effect of negation on truth value judgment. Studies (Carpenter & Just, 1975; Clark & Chase, 1972; Wason, 1961) reported that negative sentences are harder to verify than positive ones. For example, when presented with an image of several dots in one colour, participants take longer to verify "the dots aren't red" than "the dots are red". In addition, negation often interacts with sentence truth value, and produces an interaction pattern in verification time: while true affirmatives (TA) are faster than false affirmatives (FA), the opposite (often) holds for the negatives, i.e. true negatives (TN) are harder than false negatives (FN). For example, it is easier to evaluate "the dots are red" against red dots (TA) than black dots (FA), whereas it is harder evaluate "the dots aren't red" against black dots (TN) than red dots (FN). This

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result has been viewed as evidence for the rejection based account of negation processing. I argue that the dynamic pragmatic account provides a better explanation of the results, and discuss a series of experiments that test competing accounts. Chapter 5 investigates the time-course of negation processing, specifically, *when* negation-triggered contextual effect take place and *when* the meaning of negation is incorporated. I present a visual world eye-tracking study which reveals how negation processing unfolds in real time and how it differs from the processing of positive sentences. Afterwards, I discuss the findings and present a few ideas for future research in Chapter 6, and then I summarize the main ideas in conclusions. In the rest of the introduction, I define the scope of research for this thesis.

Scope of research: negative assertions

This thesis studies the processing of what is commonly referred to as "negative sentences". What are negative sentences? Although the notion sounds transparent, the nature of sentential negation has been and still is a subject of debate. In natural language use, negation can have scope over different sizes of linguistic units, such as a word (e.g. "non-words"), a phrase (e.g. "my friend lives not too far away") or a clause /sentence (e.g. "the dress isn't new"). Sentential negation operates over a wide scope, but different scholars view the nature of wide-scope negation somewhat differently. According to Fregean logic, sentential negation is a truth value operator with scope over the whole proposition. For a sentence in the form "S is not P", the scope of negation is "S is P". This view is echoed by Klima (1964), who proposes that in the deep structure, negation is in the leftmost position and only moves to its usual sentence-medial surface position via syntactic transformations. He suggests

that only sentential negation can be used with "either", "not-even", affirmative tag questions and "neither" clauses. According to Klima, in the following examples, (a) sentences contain sentential negation; (b) sentences contain negative particles or morphemes, but not sentential negation.

1a) John is quite sad, and Mary isn't happy either.

1b) John is quite sad, and Mary is unhappy *either.

2a) Writers don't accept suggestions, not even reasonable ones.

2b) Writers disregard suggestions, *not even reasonable ones.

3a) The Millers don't live far from here, do they?

3b) The Millers live not far from here, *do they?[1]

4a) Stephen doesn't like ginger, and neither does Sam.

4b) Stephen dislikes ginger, and *neither does Sam.

On the other hand, Horn (1989) defines sentential negation as "predicate denial". He follows the Aristotelian tradition that negation is a mode of predication which denies that a predicate applies to the subject. So the sentence "Coke is not nutritious" denies that being nutritious applies to coke. Note that this is still a "wide-scope" use of negation, which is different from a narrower scope use, where negation is integrated into the predicate. The wide-scope use (5) allows negation to be contracted with auxiliaries, e.g. "don't", "isn't" or "ain't", whereas narrow-scope use (6) doesn't.

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[1] It can be argued that this sentence is not really ungrammatical but perhaps not natural.

Here (5) has wide-scope negation, as the predicate *P* is denied of the subject *S*; (6) has narrow-scope negation, as the predicate *not P* is affirmed of the subject *S*.

5) S is not P. / S isn't P.

6) S is (not-P).

Sentential negation has been the subject of many psycholinguistic studies on negation. For most of them, negative sentences are viewed as propositions. The meaning of a sentence is compositionally determined by its constituents. My object of study is similar in that I am interested in the sentential negation, roughly sentences in the form "S is not P". However, I treat these tokens as **utterances** rather than propositions. I focus on how a hearer processes negative sentences produced by a speaker. This thesis assumes that psycholinguistic experiments reveal how language is processed in natural communication. Therefore, a better way to frame my scope of study would be "**negative assertions**". According to Stalnaker (1978), an assertion "expresses a proposition" in a context. The content of an assertion depends on the context and in turn changes the context. My study investigates the processing of negative assertions - utterances which express negative propositions. I assume that whether a linguistic token is uttered by a speaker in natural settings or presented in an experiment without a speaker, we adopt the same processes to interpret the linguistic tokens. With the scope of research clarified, let's move on to Chapter 1 where I survey the key findings in negation processing.

Chapter 1   Negation processing – findings and accounts

Research on the processing of negation centres on the asymmetry between affirmation and negation. (7) is an example of a negative sentence and (8) is its positive counterpart. Here negation scope over the embedded positive sentence "the door is open", which I will call the "positive argument" or the "positive counterpart"[2] of the negative sentence.

7) The door is not open. > Not (the door is open).

8) The door is open.

Psychologically, negative sentences are found to be more difficult to process than positive sentences. What's more, the positive argument of a negative sentence seems to be playing an important role in negation processing. Many studies report that participants seem to first process the positive argument. In this chapter, I first survey key findings in negation processing in 1.1, and then review current theories of negation processing in 1.2.

1.1   Findings in negation processing

1.1.1   Negation processing: the extra effort

Negation research first received significant attention in psychology in the 1960s and 1970s. A main research question was why negative sentences often take longer to process than positives. Compared to "the door is open", the sentence "the door is not

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[2] The phrases "positive counterpart" and "positive argument" are used interchangeably as they refer to the same positive proposition.

open" is one word longer. An extra word (which takes roughly 40ms to read) does not fully account for the extra time it takes to process a negative sentence compared to their positive counterparts, where the difference is roughly between 100ms to 300ms. Negation-related difficulty has been found in different paradigms such as sentence completion, sentence verification and logical reasoning. In these studies, negative items are associated with longer response times and higher error rates compared to their positive counterparts. The difficulty of negation observed in behavioral studies was confirmed in ERP and fMRI studies. In addition, drawing inferences is more difficult if the information is presented in negative form than in positive form, even if the two were equally informative (Hovland & Weiss, 1953). Also the memory of negated information is worse than that of positive material.

1.1.1.1   Sentence completion and verification

Paul Wason was an important figure in the psycholinguistic study of negation. He conducted a series of experiments studying negation in the 1950s and 1960s using sentence verification and sentence completion. For example, in his 1961 study, participants were asked to complete sentences such as (9) to (11) to make them true or false, or to verify sentences in this form. In both tasks, negative items induced higher error rates and longer response times than positive items.

9)   ... is an even number.

10) ... is not an event number.

11) ... is an odd number.

12) ... is not an odd number.

A similar effect has been found in several other sentence verification studies. These studies either involve verifying positive and negative sentences against world knowledge (e.g. Mckinstry, Dale, & Spivey, 2008; Wales & Grieve, 1969; Wason, 1961), such as "an elephant is not a mammal", or verifying sentences against pictures (e.g. Carpenter & Just, 1975; Clark & Chase, 1972; Gough, 1965; Trabasso & Rollins, 1971), such as the sentence "the dots are not red" against red or black dots. In these studies, negative sentences have longer response times and higher error rates than positive sentences.

A neuroimaging study by Carpenter and colleagues (Carpenter, Just, Keller, Eddy, & Thulborn, 1999) found that in a sentence-picture verification task, negative sentences induce increased activation in areas of the brain that are responsible for language comprehension (left posterior temporal gyrus) and for visuo-spacial processing (left and right parietal regions) compared to positive sentences. This result was taken to show that negative sentences require more effort to process. ERP studies have also found that evaluating the truth value of negative sentences require more time and cognitive effort than positive counterparts (Fischler, Bloom, Childers, Roucos, & Perry, 1983; Herbert & Kübler, 2011; Reichle, Carpenter, & Just, 2000).

1.1.1.2 Negation in logical reasoning

Negation not only makes sentence verification difficult, it also makes logical reasoning harder, evidenced by longer reaction times and biases in responses. A famous negation related reasoning bias is the "matching bias", discovered by Evans and colleagues (Evans, 1972; Evans, Clibbens, & Rood, 1996; see Evans, 1998 for a

review). In a task where participants have to evaluate a conditional rule "if the letter is a G then the number is a 4" against letter-number pairs, they tend to look for cases that match either or both components of the conditional. Pairs such as "D3" would make the rule true, but participants tend to treat these pairs as irrelevant to the rule (Johnson-Laird & Tagart, 1969). This effect is called the "matching bias" because participants tend to look for cases that have been mentioned in the rule, even if it is negated. A similar effect is found in the "Wason selection task" (Wason & Johnson-Laird, 1972). Evans (1998) suggests that "matching bias" can be explained by interpretation heuristics related to the function of negation. He called this the "not-heuristic". In natural language, a constituent is relevant even when negated. The function of negation is to "deny presuppositions rather than to assert new information" (Evans, 1998:58). For example, "I didn't go for a walk" denies the presupposition that you went for a walk. What you did do is irrelevant. According to this theory, when participants read a negative construction they do not automatically construct the complement set, rather, the positive argument remains the focus of attention. In a matching task, participants were given cards lying on a table with a letter on one side and a number on the other, as well as a rule regarding the letter and the number. They need to decide which cards to turn over to check if they fit the rule. When given a statement like "if the letter is p then the number is 7", participants do not think about the set of "non-7" or "non-p", which is why they only focus on cases containing 7 or "p", and fail to recognize that a card with the number 5 on one side needs to be checked (that it shouldn't have the letter "p" on the other side). Oaksford and colleagues (Oaksford & Stenning, 1992; Oaksford & Moussakowski, 2004) argue against Evan's "not-heuristic" account, and suggest that negation

automatically triggers comprehenders to construct a contrast set. However, constructing the contrast-set is difficult because it normally contains a large number of possible states of affairs.

Prado and Noveck (2006) tested these two accounts using the conditional rule task. Participants verified four types of sentences about letters and shapes in "if…then…" constructions against visual stimuli. The four types of sentences were affirmative antecedent, affirmative consequent (AA): if p then q; AN: if p then not q; NA: if not p then q; and NN: if not p then not q. AN sentences such as" if there is an H then there is not a square" were the critical items. The visual stimuli were letters presented in geometric shapes (e.g. an H inside a circle). The "Not-heuristic" account (Evans, 1972, 1998) would predict that rejecting an AN sentence is easier than affirming one, as in the former case, both items in the visual stimuli would have been mentioned in the sentence. On the other hand, the automatic contrast-set account (Oaksford & Moussakowski, 2004) would predict the opposite. They found that the rejection of AN items was easier than confirmation. This suggests that sentences like "if there is an H then there is not a square" only primed elements that were mentioned, even if they were negated. In other words, reading "not a square" does not prime shapes other than square. Their results support the "not-heuristic" view: negation does not automatically prime a search for the alternatives.

1.1.1.3   Memory of negated material

Negation has been shown to have an impact on memory. A study by Cornish and Wason (1970) found that people remember positive sentences more accurately than

negative ones. What's more, participants are more likely to misremember a negative sentence to have appeared in a positive form, than to misremember a positive senesce to have appeared in the negative form. Many errors with negative sentences involved "rephrasing" the content in a positive form.

Howard (1975) studied the effect of negation on memory search. Participants were shown a set of letters. In the *plus* condition, participants had to decide whether the probe was a member of the set, i.e. answering "yes" when the probe was a member and "no" otherwise. In the *minus* condition, participants had to decide if the probe was *not* a member (reversed answers to *plus* condition). They found that performance in the *minus* condition was worse than the *plus* condition in both reaction time and accuracy. Howard attributed this difference to the difficulty of representing information in the negative form.

1.1.1.4 Acquisition of (truth functional) negation

Given the difficulty in processing negative sentences among adults, it will not be surprising that children experience some difficulty acquiring negation. Although young children often start using negation in one-word stage, they don't master all the main uses of negation until much later (Pea, 1980). Bloom (1970) proposed that children acquire three categories of negation in sequence: nonexistence, rejection and denial. The three categories can be illustrated with the following examples. Nonexistence is used when a child expects a referent in context, but cannot see the referent. An example of such use is *no pocket* (in mommy's shirt). Rejection is used when the referent is present in context, but the child is rejecting or opposing it. An

example of such use is "no dirty soap", meaning "I don't want dirty soap". Denial is used to mean that a proposition is not true or a situation is not the case, such as saying "no truck" after an adult gave the child a car and said "there's the truck". However, this acquisition order is not seen in all children. Pea (1980) showed that many children first express rejection non-verbally, by shaking their head. He thus proposed a different development sequence: rejection (typically nonverbal) – disappearance –truth functional negation.

However, what *is* universal is that denial, or the truth functional use of negation is the last of the three to appear, which happens at around 24 months. The late occurrence suggests that truth functional negation is cognitively complex. Pea (1980) proposed an explanation by comparing the mental representations of the three types of negation. Rejection involves expressing one's negative attitude or emotion towards a present referent, thus it requires no explicit mental representation. Disappearance, such as uses like "gone" or "no more" when a referent has disappeared from sight, requires mental representation of the referent. Truth-functional negation, however, requires abstract mental representation in a much higher level of complexity. Unlike disappearance negation, truth functional negation involves commenting on the abstract representation of complete propositions, the meaning of which is of a higher logical type than disappearance negation.

1.1.2 Negation and the representation of the positive counterpart

In addition to the difficulty of negation, another interesting and prevalent finding concerns the role of the positive counterpart in negation processing. Studies (e.g.

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Dale & Duran, 2011; Fischler et al., 1983; Hasson & Glucksberg, 2006; Kaup, Yaxley, Madden, Zwaan, & Lüdtke, 2007; Lüdtke, Friedrich, De Filippis, & Kaup, 2008) found that in the early processing stage (approximately between 0ms to 800ms after the offset of the sentence stimuli), negation seem to be ignored and negative sentences seem to be processed as if they were positive.

1.1.2.1   In probe recognition task

Probe recognition tasks have been used to study the activation level of the representation of the positive counterpart. They found that shortly after reading a negative sentence, participants simulate the situation consistent with the positive argument. Concepts consistent with the positive counterpart are more active than concepts consistent with the negative sentence meaning. For example, shortly after reading "the door isn't open", participants are faster to respond to an image of an open door than a closed door.

In a series of studies using visual probe recognition, Kaup and colleagues investigated the stages of representations during negative sentence processing. The paradigm is based on a study by Zwaan and colleagues (Zwaan, Stanfield, & Yaxley, 2002). In this study, participants were presented with sentences such as "*the ranger saw an eagle in the sky/nest",* and then (250ms after the sentence) saw a picture depicting the noun mentioned in the verb phrase (*eagle).* The picture either matched or mismatched the implied shape (a flying eagle or a resting eagle). Participants indicated whether the object was mentioned in the sentence, which for experimental items was always "yes". They found that participants took longer to respond to a

mismatching picture than a matching picture. They concluded that the results suggest that participants routinely infer the implied shapes of objects during sentence comprehension, and construct mental simulations. Kaup, Yaxley, et al. (2007) used this paradigm to investigate what representations are constructed when processing a negative sentence. Participants read sentences such as "there was no eagle in the sky", and 250ms after they finish reading the sentence, saw a picture of the mentioned item (eagle) that either matched or mismatched the shape implied by the sentence. If participants infer the implied shape according to the negative sentence and construct a mental simulation, they should respond faster to a matching (resting eagle) than a mismatching (flying eagle) picture, just like with the positive sentences. However, the results showed that responses to a *mismatching* picture were faster, suggesting that participants simulate the situation of the positive counterpart when processing a negative sentence.

Kaup, Zwaan, & Lüdtke (2006) studied the processing of negative sentences with binary predicates, such as "the door was not open". Participants read the sentences and after a delay saw a picture that either matched or mismatched the implied shape of the target item (a closed or open door), and named the object out loud. The delay was varied at either 750ms or 1500ms. They found that at 750ms delay, there was a match facilitation in response for positive but not negative sentences. At 1500ms delay, the match facilitation is not seen in positive sentences, but is present for negative sentences. Kaup and colleagues concluded from the results that in the early stage of negative sentence processing, comprehenders first simulate a situation consistent with the positive counterpart. This representation is subsequently rejected

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and replaced with a representation consistent with the negative sentence meaning. They proposed the two-step simulation account of negation processing. I will review this account in more detail in section 1.2.2.

Hasson and Glucksberg (2006) studied metaphor comprehension using word probe recognition. They used a lexical decision task after presenting sentences like "my brother is (not) a rock". The critical probe word was consistent with the metaphor's vehicle (e.g. strong). The delay offset varied at 150ms, 500ms, or 1000ms. They found that for positive metaphors, response times to vehicle-consistent words (e.g. strong) were facilitated at all delays. For negative metaphors, there was similar facilitation initially (at 150ms and 500ms delays). However at longer delay (1000ms), this facilitation was gone. They suggested participants initially represent the positive counterpart of the negated concept, and later suppress it.

1.1.2.2   In sentence verification

In sentence verification, studies found that negation not only makes sentence verification more difficult, it can also interact with sentence truth value: while it is easier to judge a true positive than a false positive, the opposite (often) holds for negative sentences. For example, in Clark and Chase (1972), sentences such as (13) to (16) were shown alongside a picture that makes the sentence true or false.

13) The plus is above the star. (True Affirmative, abbrev as TA)

14) The star is above the plus. (False Affirmative, FA)

15) The star isn't above the plus. (True Negative, TN)

16) The plus isn't above the star.(False Negative, FN)

Picture:

$$+$$
$$\star$$

Results from all sentence verification studies found that when verifying a positive

sentence, the true ones are easier (TA<FA). With negative sentences, many studies

(e.g. Carpenter & Just, 1975; Clark & Chase, 1972) found that true negative

sentences are harder than false ones, thus reporting a polarity by truth value

interaction (TA<FA<FN<TN)[3]. This pattern is interpreted in terms of a strategy

based on the truth-functional property of negation. When presented with a negative

sentence, participants first represent and evaluate the truth value of its positive

argument (the corresponding affirmative), and then reverse the truth-value. The

argument of TN is FA, and the argument of FN is TA. Given that response latencies

are shorter for TAs than for FAs, evaluating the argument is faster for FNs than for

TNs. Assuming that the cost of reversing truth-value is constant, it explains why TNs

have longer response latencies than FNs.

Dale and Duran (2011, experiment 1) conducted a sentence-world knowledge

verification study using mouse-tracking ('Elephants are not small/large').

Participants were presented with the sentence word by word in the bottom centre of

the screen, and then moved the mouse cursor from the bottom centre to either

"TRUE" or "FALSE", which were in the top left and right of the screen respectively.

Mouse movement trajectory and speed were measured. They found that mouse

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[3] Some studies reported that truth and false negative sentences take equally long, yet others report that truth sentences take less time to judge, whether they are positive or negative. I will review the literature in more detail in chapter 4.

movements involve a higher number of directional flips between "True" and "False" when verifying a negative sentence than a positive sentence. The deviation of such flips is larger in negatives compared to positives. Also, there was a polarity by truth-value interaction in the number of directional flips, i.e. there were less flips in TA than FA, and less flips in FN than TN. They suggested that participants first considered the truth-value of the affirmative counterpart when verifying negative sentences. A similar effect has been reported by Mckinstry et al. (2008).

1.1.2.3 In ERP studies

ERP studies (Fischler et al., 1983; Lüdtke et al., 2008) found that certain kinds of true negatives (e.g. A robin is not a tree) gave rise to greater N400 effects than corresponding false negatives (A robin is not a bird), while the corresponding false affirmatives (a robin is a tree) predictably gave rise to greater N400 effects relative to true affirmatives (a robin is a bird). Fischler et al. (1983) attributed this reversal of the normal N400 effect to the idea that participants first process the positive argument when processing a negative sentence. Thus, in the early stage when the N400 effect is found, a negative sentence "a robin is not a bird" involves processing "a robin is a bird", thus triggering the same results as its positive counterpart.

Lüdtke et al. (2008) presented participants with positive and negative sentences such as "in front of the tower there is a ghost/ there is no ghost", and then a picture that is either consistent or inconsistent with the sentence meaning at either 250ms delay or 1500ms delay. The N400 amplitude was measured time-locked to the picture. At 250ms delay, they found no negation effect. That is, a picture of a ghost in front of a

tower is primed equally by a positive and a negative sentence, both eliciting a smaller N400 than the mismatching picture, suggesting that negation is not initially integrated. At 1500ms delay, pictures that are consistent with the sentence meaning are more primed, suggesting that negation is fully integrated at this point. They concluded that negation doesn't supress the priming effect of word under its scope, and the early stage of negation processing involves processing the positive argument.

1.1.2.4 When it does not happen

While it seems that participants often represent the positive counterpart when processing negative sentences, some studies suggest that they do not always. In the ERP literature, Nieuwland and Kuperberg (2008) showed that contextually felicitous True Negatives do not give rise to a greater N400 effect compared to either True Affirmatives or False Negatives. When participants read pragmatically licensed negative sentences, such as "With proper equipment, scuba-diving isn't very safe/dangerous", words that make the sentence false (safe) elicited bigger N400 than words that make the sentence true (dangerous). However, when participants read pragmatically unlicensed negative sentences, such as "Bulletproof vests aren't very safe/dangerous", words that make the sentence false (safe) elicited *smaller* N400 than words that make the sentence true (dangerous). They suggest that there is no principled obstacle for participants to incorporate negation immediately. With appropriate context, participants do not have to first process the positive argument, and that the meaning of negation can be incorporated immediately.

Similarly, Dale & Duran (2011, Experiment 2 &3) showed that the more contextual support that the items have, the less the tendency to consider the positive counterpart. Using a mouse-tracking paradigm, participants read short passages such as 'You want to lift an elephant?' the mother said to her child, 'but elephants are not small", and judged the sensibility of the adults' statement. They found no polarity by truth value interaction, i.e. true statements elicited fewer flips along the answer axis than false statements regardless of the sentence polarity.

In addition, fMRI studies (Tettamanti et al., 2008) show that while reading a positive sentence with action verbs (e.g. 'grip', 'clasp') activates the motor regions (left-hemispheric action-representation system), negation modulates this activity. Specifically, negative sentences tend to show decreased activation relative to positive sentences (see also Tomasino, Weiss, & Fink, 2010).

1.1.3   Negated words are less accessible

Studies found that the concept and/or the linguistic form of the constituent in the scope of negation can be suppressed/ deactivated in the late processing stage (Hasson & Glucksberg, 2006; Kaup & Zwaan, 2003; Levine & Hagaman, 2008; MacDonald & Just, 1989). Studies in this area investigated two related but different questions:

a. Whether the accessibility of a word is reduced when it is negated compared to when it is affirmed. For example, whether the accessibility of "cake" is reduced after reading "Jane didn't bake cakes" compared to "Jane baked cakes".

b. Whether the accessibility of the positive argument of negation is reduced compared to the concept consistent with the negative sentence. For example, whether "open" is less accessible than "closed" after reading "the door isn't open".

Literature on these two topics sometimes refers to the suppression/ deactivation effect of negation as the general topic, which can be confusing. I will review studies relevant to these two questions separately.

Question (a): is a concept less accessible when it is negated than when it is affirmed? Studies by MacDonald & Just (1989) offers some support. In their paradigm, participants read sentences in a moving-window display, such as "Almost every weekend, Elizabeth bakes no bread but only cookies for the children", and afterwards (five spaces later) saw the probe word, which was the negated noun (bread) or non-negated noun (cookies). They either made a lexical decision on this probe, or named it out loud. Response times were longer when the probe was negated than when it was affirmed. In a follow-up experiment, participants named probes that are associated with negated or non-negated nouns (e.g. *butter* was an associated word to *bread).* In this case, although response times were numerically longer when the probes associated with negated than non-negated nouns, the difference did not reach significance. Put together, response times to negated nouns are reliably slower than response times to non-negated nouns, but responses to semantic associates to negated and non-negated nouns are not significantly different. They concluded that negation

reduces the accessibility of the linguistic form of words in its scope, but this effect may not spread to associates of negated words.

Levine & Hagaman (2008) conducted a study with similar sentences, but investigated whether negated concepts can interfere with anaphor resolution. Previous studies (Garrod & Sanford, 1977) found that when a categorical anaphor (e.g. the bird) refers to a highly typical member of the category (e.g. robin), it is processed more quickly than if it refers to a less typical member (e.g. goose). Levine and Hagaman found that when reading passages such as "Justin bought a mango but not an apple / a kiwi. He ate the fruit", reading time for the target sentence ("he ate the fruit") was slower when the negated noun was highly typical (apple), than when it was less typical (kiwi). The results suggested that the negated concept was considered during anaphor resolution. A follow-up memory recall experiment using similar items found no difference in the memory of negated and non-negated nouns. They concluded that their results show no suppression of negated concepts.

Kaup and colleagues investigated whether the absence or presence of a concept in the situational representation affects the accessibility of the concept. Their 2001 study (Kaup, 2001) used a probe recognition task. Participants read sentences like "John was building the castle but not the church", or "Sarah was burning the letters but not the photographs". They were presented a probe word at the end of the sentence after a 2500ms delay. They found that for both creation and destruction sentences, response times to the negated noun was significantly slower than non-negated noun. In addition, the negation effect was larger for passages with

constructing activities than destroying activities. In a similar study (Kaup & Zwaan, 2003), participants read sentences such as *Sam was relieved that Laura was wearing her pink dress"* (presence condition) or "*Sam wished that Laura was not wearing her pink dress"* (absence condition). The critical probe word is "pink". The probe presentation delay was varied at 500ms and 1500ms. They found that at 500ms delay, response times were longer for negative than positive, and presence-absence had no effect. At 1500ms delay response times were longer if the concept was absent than if it was present. The effect of negation was much weaker. The results support the finding from McDonald and Just that at least the word's linguistic form is less accessible if it is negated than affirmed. In addition, the authors suggested that how much negation reduces the accessibility of words under its scope is modulated by whether the concept is present or absent in the situational representation.

Giora and colleagues (Giora & Balaban, 2005; Giora, Fein, Aschkenazi, & Alkabets-zlozover, 2007; Giora, 2006) argue that negation does not necessarily suppress the core meaning of the concept under negation. In their 2005 study, participants read sentences such as "the instrument is/is not sharp", and then made a lexical decision on a probe word that is related to the positive argument (e.g. piercing). At 100ms delay, response times to the probe word were comparable between positive and negative sentences. Their results suggest at a very short latency, the accessibility of words under negation and affirmation are comparable.

Overall, studies investigating Question (a) seem to offer contradictory results. However if we consider the details of these studies, we can piece together the

findings in a coherent picture. McDonald and Just found that the linguistic form, rather than the conceptual representation of the negated word is less accessible, and this effect was found at least 1000 ms after the stimuli was first encountered[4]. In comparison, Giora & Balaban (2005) found no deactivation effect when the probe appeared 100ms after the stimuli, suggesting that the suppression effect takes some time (more than 100ms). This is also supported by studies by Kaup and colleagues. Levine and Hagaman found that negated concepts *are* considered during anaphor resolution. However, this result does not show that the negated concepts are as activated as the affirmed concepts, and thus doesn't contradict the above mentioned results. They also found that in a post-hoc memory recall test, memory of negated words is not worse than non-negated words. This result suggests that either the suppression effect is short-lived, or that it does not affect memory of the negated concept, however this piece of evidence is at odds with findings suggesting memory of negated materials is worse than affirmed materials. Overall, these studies suggest that negation seems to reduce the accessibility of the *linguistic form* of words in its scope. This effect is not immediate and can be influenced by the presence or absence of concepts in situational representation.

Question (b): Is the accessibility of the positive argument of negation reduced compared to the meaning consistent with the negative sentence? In the section 1.1.2, we saw that the positive argument of negation is often activated in the early stage of

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[4] This time span is my estimation. In their experiment, the probe appeared five spaces after the end of the coda sentence, and the gap between the negated noun and the probe word varied based on its location. Based on their reported reading times (around 350 per word), the gap is likely over 2000ms if the negated noun appeared early, or around 1000ms if the negated noun appeared late.

negation processing, suggesting that the answer to the question is "no" during the early processing stage. Is the accessibility of the positive argument reduced later? Most studies show that the representation of the positive argument is short-lived, and comprehenders switch to a representation consistent with the negative sentence meaning later on (as in Hasson & Glucksberg, 2006; Kaup et al., 2006). These findings suggests that the answer to question (b) is "yes" in the late processing stage.

However, Giora et al. (2007) argues that suppression of the positive argument following negation is not obligatory. Whether the positive argument or concepts consistent with it are suppressed is influenced by discourse considerations, such as whether the concept is the topic. Their 2007 study investigated the accessibility of negated concepts with coherent and incoherent oncoming discourses. Participants read sentences word by word, such as "the train to Boston was no rocket", followed by a coherent sentence "the trip to the city was fast enough", or an incoherent sentence "the old man in the film spoke fast". Reading time of the target word "fast" is shorter in the coherent discourse condition compared to the incoherent condition. They concluded that the suppression of the concept related to the negated word (positive argument) is sensitive to discourse considerations.

1.1.4   Negation is not difficult with context

By now we have seen many different findings suggesting that negation is difficult. However, the vast majority of these studies tested negation processing without context. The relation between negation and context has been highlighted by many linguists and philosophers such as Bertrand Russell and Larry Horn. Many

psycholinguistics studies show that with appropriate contextual support, negative sentences are not difficult to process (such as Dale & Duran, 2011 experiment 3; Giora, 2006; Nieuwland & Kuperberg, 2008).

Wason (1965) suggested that negation requires a context of "plausible denial" Negation is supported by a context in which a salient expectation can be denied. Specifically, he proposed two hypotheses: the exceptionality hypothesis and the ratio hypothesis. The exceptionality hypothesis says that when people describe the properties of an object, it is easier to deny that an exceptional item has a typical property (e.g. a whale is not a fish), then to deny that a typical item has an exceptional property (e.g. a trout doesn't have lungs). The ratio hypothesis says that when there is a set of objects with different properties, it is easier to describe an object in the minority set to not have the property of the majority set than the other way round. For example, when presented with the items "apple, pear, orange and cabbage", it is easier to complete the sentence "a cabbage is not (a fruit)" than to complete the sentence "an apple is not (a vegetable)".

Wason (1965) tested these two hypotheses using an array of eight blue or red circles, seven of which were in one colour and one in the other colour, and participants were divided into the "exceptionality" condition and the "ratio" condition, each testing their corresponding hypothesis. In the "exceptionality" group, the circles were numbered. Participants first described the array so that the array could be identified, e.g. "circle No. 4 is red and the rest are blue", and then completed sentences in a similar form. The sentences were positive or negative, and either about the special

circle or one of the similar circles. For example "circle No. 4 is (not) …". In the "ratio" group, the circles were not numbered. Participants first stated out loud the number of items in each colour, e.g. "seven circles are blue and one circle is red". Then they were given positive or negative sentences to complete, e.g. "exactly one circle is (not)…" or "exactly seven circles are (not)…".

Wason predicted that in both conditions, the difference in sentence completion response times between negative and positive items would be smaller for the dissimilar circle than for similar circles. This prediction was confirmed in the "exceptionality" condition but not in the "ratio" condition. Wason attributed this difference to the description in the coding stage. When participants described the array in the "exceptionality" condition, the properties of the special circle is viewed against the similar circles. Therefore the two are reciprocally related. However in the "ratio" group, participants coded the array as two independent groups. Therefore the special item is not evaluated against the similar group. Wason's results suggest that being a minority or having a unique property doesn't reduce the processing cost of negation about the item. Rather, it depends on the accessibility of a positive representation of the corresponding majority set in the context.

Glenberg, Robertson, Jansen, & Johnson-Glenberg (1999) studied the effect of explicit context for negative sentence processing. They propose that a stand-alone negative sentences is often more ambiguous than the positive counterpart. Therefore negation is not very effective for introducing new information. The under-informativeness is reflected in longer processing times. When negation is supported

by context, however, it can introduce new information by eliminating prior expectations or uncertainties. In this case, the processing time of a negative sentence should be comparable to that of a positive sentence. Their 1999 study tested this proposal. Participants read passages containing an introduction, a supporting or non-supporting context, a continuation sentence, and a critical sentence that is either positive or negative.

17) **Introduction**: *Marcy needed a new couch for her family room.*

    Context:

    Supporting context: *She wasn't sure if a darkly coloured couch would look best or a lighter colour.*

    Non-supporting context: *She wasn't sure what kind of material she wanted the couch to be made of.*

    Continuation: *She finally picked one out and had it delivered to her home.*

    Critical sentence:

    Critical positive: *The couch was black. It looked very nice in her family room.*

    Critical negative: *The couch wasn't black. That probably would have been too dark.*

Reading times of the critical sentence "the couch was/wasn't black" were measured. Results showed that with non-supporting context, negative sentences took significantly longer to read than positives. With supporting context, there was no

difference between negatives and positives. The results suggested that negative sentences need not be difficult to process when there is contextual support.

Lüdtke & Kaup (2006) conducted a similar study. They proposed that contexts which reduce or eliminate negation cost should either explicitly mention the positive counterpart, or strongly imply a positive expectation. In the experiment, participants read passages containing a positive or negative sentence preceded by different context sentences.

18) *On her way to the pool, Danielle wondered …*

    Context (a): Whether the water would be warm.

    Context (b): Whether the water would be warm or cold.

    Context (c): What the water would be like.

    The water was (not) warm.

They found that reading times of the last sentence were in general longer if the sentence was negative. Within the negative condition, reading times were faster when the positive counterpart was explicitly mentioned, as in contexts (a) and (b), than when it was not mentioned, as in context (c). In a second experiment, they found that when participants read negative sentences in contexts that strongly imply a positive expectation, negation cost is completely eliminated.

1.2   Current Accounts

We have seen that negative sentences tend to be more difficult to process than positive sentences. The effect was found in paradigms such as sentence completion, sentence verification, logical reasoning and memory recall. Truth functional negation is hard for children to acquire. Contextual support can greatly reduce or eliminate negation related processing costs. In addition to difficulty, experiments in negation processing often, but not always, involve the representation of the positive counterpart, and this effect was seen in a wide range of studies, including sentence verification, probe recognition and ERP studies. The representation of the positive counterpart occurs in the early stage of negation processing, and its activation is short-lived. Negation also seems to reduce the accessibility of the words in its scope.

So how is negation processed? These effects might have more than one cause. However, based on the principle Occam's razor, a theory that explains more findings is favoured over a theory that explains less. Most current theories on negation processing link the processing difficulty with negation with the representation of the positive counterpart, or with the contextual effects, or both. No theories make a direct connection between processing difficulty and the representation of the positive with the deactivation/suppression effect of negation convincingly. Given the focus of my investigation, I will focus on these two sub-questions: 1. why are negative sentences difficult to process without-context? 2. why is the positive counterpart often, but not always, represented/activated? This section reviews current accounts of negation processing.

1.2.1 Grammatical transformation

Some of the early accounts of negation processing focus on the structural complexity of negative sentences. This approached is influenced by Chomsky's transformational grammar (Chomsky, 1957), which suggests that the majority of the sentences are derived from a set of basic or kernel sentences by means of transformations. Negation is one such transformation. For example, the sentence "the boy hasn't kicked the ball" is derived by applying negation to the kernel sentence "the boy has kicked the ball". It was proposed (Miller 1962; Slobin 1966) that grammatical transformations incur processing cost. Transformed sentences take longer to process than kernel sentences. Sentences that require two or more transformations take longer to process than those that require only one transformation. Not all transformations are equal; some require more processing effort than others.

Miller (1962) suggested that passive transformation is more complex than negation. He tested the effect of grammatical transformation on processing cost by presenting participants with a set of kernel sentences such as "Jane liked the woman", as well as passive and/or negative sentences transformed from these kernel sentences, such as "The woman was liked by Jane" (passive), "Jane doesn't like the woman" (negative) and "The woman wasn't liked by Jane" (passive and negative). The sentences are presented in two lists. Participants were asked to pair the sentences up if they have the same core structure. In the control condition, the two sentences are identical. For experimental sentences, Miller subtracted the time it takes to match two identical sentences from the time it take to match a complex sentence with a kernel sentence,

and called this difference "transformation time". He found that both negation and passivation have a transformation time significantly longer than zero, and that transformation time of passivation is longer than that of negation.

However, the time difference in this task can be caused by visual differences between sentences. Participants were not checked on comprehension, therefore they could have simply matched the sentences by their visual form. The difference between the form of a passive sentence and its active counterpart is bigger than the difference between a negative sentence and its positive counterpart. In addition, this result cannot determine whether the extra time is due to syntactic transformation or due to differences in sentence meaning and/or structure frequency. Gough (1965) argues syntactic complexity alone cannot account for all the extra cost associated with negation. The semantics of negative sentences must also play a role, since in verification tasks negation interacts with sentence truth value in response times. He also pointed out that active and positive sentences are more frequent than negative and passive sentences. The extra matching time could be explained in terms of frequency effect. Slobin (1966) argued that if syntactic complexity explains the extra processing time, passive sentences should take longer. However, they found that negative sentences take longer to verify, which suggest that negation triggered difficulty must have a semantic element.

In addition to these arguments, it is clear that the syntactic account does not explain why context plays an important role in processing difficulty, or why the positive counterpart is often represented. Due to the limited explanatory power and the

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arguments above, syntactic complexity accounts at best explain only some of the difficulty associated with negation. To account for the other processing effects, we need alternative theories.

1.2.2   Rejection accounts

The most popular perspective suggests that negation is difficult to process *because* we have to represent the positive counterpart first. The meaning of negation is only incorporated in a second step. This idea draws from the function of negation as a truth-function operator. A sentence such as "the door is not open" has the structure "not (the door is open)". To be able to process the negative sentence, we must first process the positive counterpart. I will call these accounts rejection accounts.

Rejection accounts differ in the nature of representation. Propositional models (Carpenter & Just, 1975; Clark & Chase, 1972) suggest that negative sentences are represented in a propositional format by multiple constituents. The positive argument embeds under the negation operator. The two-step simulation account (Kaup, Zwaan, et al., 2007) agrees with idea of embedding the positive counterpart, but states that mental representations are perceptual in nature.

1.2.2.1   Propositional models

Propositional models (Carpenter & Just, 1975; Clark & Chase, 1972) were proposed to account for the findings in sentence – picture verification tasks. Clark and Chase (1972) asked participants to verify sentences such as "Star isn't above plus" against a picture of a star and a plus arranged vertically. They proposed that sentences are

represented in a propositional format. The negative sentence A isn't above B is represented as the positive proposition (A above B) embedded under the negative polarity marker, i.e. "Not (above [A, B])". Pictures are represented in the same format, but only ever using positive propositions. During the verification process, the representations are compared from the inner most constituent. This process is motivated by Klima's (1964) analysis of the role of negation in propositional logic. As an operator applied to a proposition, the meaning of negation can only be incorporated once the embedding argument is processed. By this account, the representation of the positive counterpart is obligatory. The extra embedding step explains why negative sentences are harder to process than positive sentences. The details of these models and their application in sentence verification will be discussed in Chapter 4.

A similar theory, called Model theory, is proposed by Khemlani, Orenes and Johnson-Laird (2012). They suggest that language comprehension involves two processes: the first process represents the intension of the sentence based on rules of compositional semantics. The second process uses the representations from the first process to construct the extension- the mental models of the situation. During the first process, the representation of a negative sentence would be similar to the proposal by propositional accounts[5]. In the second process, a positive sentence is represented as models of the possible situations it refers to. Negation is an operator that takes the set of models corresponding to the positive argument, and returns its

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[5] However, Khemlani et al., (2012) proposed that comprehenders have the heuristic of interpreting a negative sentence with a narrow rather than a wide scope. For example, in a sentence such as "A is not B", the narrow scope of negation is "is B", in which case it is only the positive VP that is embedded under negation.

complement set. According to this theory, negation related cost comes not only from the embedding step in the first process, but also from drawing inferences (calculating a complement set) in the second process. It thus predicts less processing load when the complement set contains fewer members. For example, "the cat is not dead" should be processed faster than "the cat is not black", as the compliment set of "dead" contains only "alive", while the compliment went of "black" contains many members.

1.2.2.2 Two-step simulation account

The two-step simulation account follows the embodied language processing view that language comprehension is achieved through the construction of mental simulations (Barsalou, 1999; Glenberg, Robertson, Jansen, & Johnson-Glenberg, 1999; Glenberg, 1997; Zwaan, 2004). These simulations are perceptual in nature, i.e. they are similar to representations constructed in nonlinguistic cognition, using sensorimotor systems. Not only are concrete concepts represented perceptually, even abstract concepts are grounded in perception. One of the biggest hurdles for this view is to explain how abstract linguistic operators such as negation are represent perceptually. Kaup and colleagues (Kaup, Yaxley, et al., 2007; Kaup et al., 2006; Kaup, Zwaan, et al., 2007) propose that negation is processed by way of two-step simulations. First, comprehenders construct a mental simulation of the positive counterpart; then this simulation is rejected and replaced with one consistent with the sentence meaning. The meaning of the negation operator is encoded by the deviation of the two simulations. When a negative sentence does not specify the actual situation (for example, "Susan's dress is not red"), the second stage simulation will

simply contain unspecified properties (in this case representing Susan with a dress of an unspecified colour). The authors propose that experiential simulations, unlike pictorial representations, are much less restricted in terms of what can be left unspecified.

Like propositional models, the two-step simulation account explains the process cost of negation in terms of a two-step process. The representation of the positive counterpart is an obligatory first step. If the representation of the positive counterpart is available prior to encountering negation, all that's left to do is to reject the first simulation and simulate the actual situation. The theory thus predicts that when the prior context contains the positive counterpart, negative sentences take less time to process.

1.2.2.3 Criticism of rejection accounts

Rejection accounts can explain both the extra cost of negation and why the positive counterpart is represented. However, they are faced with at least two challenges. First, many studies found that representing the positive counterpart is not mandatory, sometimes even when the sentences are presented without context. These findings are incompatible with rejection accounts. Second, rejection accounts suggest that the meaning of negation cannot be incrementally incorporated. This implication seems at odds with abundant evidence for incremental language processing. Psycholinguistic research has found that comprehenders activate linguistic and even pragmatic information as soon as cues are encountered, and use such information to form predictions incrementally. For example, as soon as hearing "the boy will eat…", but

not "the boy will move…", participants predict words for foods (Altmann & Kamide, 1999). Recently, research has also grown in the online integration of pragmatic information. We can integrate common ground and speaker's epistemic state at the earliest moment and use such information to predict upcoming referents (Breheny, Ferguson, & Katsos, 2013; Heller, Grodner, & Tanenhaus, 2008); we can access scalar implicatures on-line with little or no delay, especially with contextual support (Breheny, Ferguson, & Katsos, 2012; Grodner et al., 2010; but see Huang & Snedeker, 2009); we infer information about the speaker, using accents and cultural heuristics, and anticipate upcoming words in a sentence (van Berkum, van den Brink, Tesink, Kos, & Hagoort, 2008). Such information interacts with linguistic information during online sentence processing. In light of the findings on incremental processing, rejection accounts must explain why negation is an exception.

1.2.3 Contextual approach

The contextual approach focuses on the importance of context for negation processing. Without context, negative utterances have two pragmatic drawbacks: infelicity and under-informativeness.

The philosophy and psycholinguistics literature have both recognized the infelicity of negative utterances without context. Bertrand Russell (1948) said that "perception only gives rise to a negative judgment when the correlative positive judgment has already been made or considered". Wason (1965) argues that negative utterances are often used to deny or contradict a positive proposition. Negative sentences out of

appropriate context are often infelicitous, and therefore hard to process (in the majority of psycholinguistic research on negation, sentences are presented without context). A similar idea was voiced by Horn (1978) appealing to Gricean maxims. Philosopher Paul Grice introduced four maxims that govern our conversational behaviour: Quality, Quantity, Relevance and Manner (Grice, 1975). Horn (1978) suggests that a negative sentence is relevant to the consideration of its positive counterpart. When the positive counterpart is not in the context, uttering a negative sentence violates the maxim of Relevance.

A second pragmatic effect discussed by contextualists (Givón, 1978; Horn, 1989; Leech, 1981) is that stand-alone negative sentences are often less informative than their positive counterparts . The sentence "the girl's dress is red" has a determinate set of verifying situations. We know more precisely what the world is like for this sentence to be true. In this respect, "the girl's dress is not red" is less determinate. We cannot represent all possible worlds that make the sentence true. In every day terms, a negative sentence if often less informative compared to its positive counterpart. Assuming that the speaker is being cooperative when uttering a negative sentence, the comprehender must draw an inference which justifies the apparent violation of the maxim "being informative". However if being under-informative is a cause for the extra processing cost, it shouldn't apply to negative sentences with a binary predicate. The sentence "the fish is not dead" is just as informative as "the fish is alive".

1.2.3.1 Criticism of the contextual approach

Current contextual approaches explain the difficulty of negation in terms of its requirement for specific context. While this line of thought seems plausible, as well as being empirically supported, it raises a number of important questions that are yet to be answered. First, negation is not alone in requiring special contextual conditions for its appropriate use. It is widely agreed that virtually every utterance contains elements that require some kind of contextual completion for its full interpretation - for instance, anaphoric or pronominal elements, tense, quantifiers and so forth. Moreover, some positive sentences require a 'context of plausible assertion' just as much as negative sentences require a 'context of plausible denial'. I.e. just as much as 'The door is not closed' is typically produced when whether the door is closed is at issue, 'the door is open' is typically produced when the state of the door is at issue. So the first question is, what is it about the contextual demands of negative sentences that make them particularly difficult to process when presented out of the blue, compared to their positive counterparts?

Second, as mentioned above, the positive argument of a negative sentence is often, although not always, represented during early stages of negation processing. Following the current contextual approach, Nieuwland and Kuperberg (2008) suggest that with the right contextual support, the positive argument need not be represented for comprehension. Similar conclusions are drawn in Dale and Duran(2011). However, no contextual account so far explains why when lacking contextual support, the positive argument IS represented in the first place.

1.3 Summary

Psycholinguistic studies found that without contextual support, negative sentences are more difficult to process than their positive counterparts. In the early stages of negative sentence processing, the positive counterpart is often represented. However, with enough contextual support, both effects diminish or disappear. In addition, negation can reduced the accessibility of words under its scope.

Current accounts of negation processing fall into three categories: grammatical, rejection and contextual. The grammatical transformation view suggests that the syntactic structure of a negative sentence is more complex than its positive counterpart, which is the cause for extra processing effort. This view can explain a very limited set of findings. Rejection accounts draw from the idea that negation is an external operator on a positive proposition. The extra cost of negation comes from the extra step of embedding. However, these accounts fall short of explaining the findings that the positive argument is not always represented. Also their implication is at odds with evidence for incremental language processing. Contextual approaches focus on the cost of lack of context. They argue that with appropriate contextual support, negation is not difficult. However, these approaches haven't spelled out how contextual requirement of negation triggers more processing cost than their positive counterparts. They also cannot explain why it is that when we process negative sentences without context, we often represent the positive argument.

Chapter 2　Dynamic pragmatic account of negation processing

In the previous chapter, we saw that without context, negative sentences are more difficult to process than positive sentences. This difficulty is reduced or eliminated with appropriate contextual support. In addition, in the early stages of processing, the positive counterpart is often represented. Current theories of negation processing can be divided into three categories: grammatical transformation, rejection-based and contextual, none of which explain all the relevant empirical findings.

It is clear that context is important for the use negative sentences. Intuitively, an out-of-the-blue negative sentence such as "I didn't see Chomsky today" seems infelicitous, while the positive counterpart "I saw Chomsky today" is more natural. There is no doubt that in natural conversations, context plays an important role in utterance interpretation in general. The linguistically coded meaning almost always underdetermines the communicated meaning of an utterance (Bach, 1994; Carston, 1988; Recanati, 1989, 1994). Current processing accounts of negation don't deny this, but they assume that when participants read or hear sentences without context, they process only the semantic meaning. Therefore, the processing effects associated with negation (such as extra difficulty and the representation of the positive counterparts) must be caused by processing the semantic meaning of negative sentences.

I will now propose a different account of negation processing; one that doesn't detach sentence processing from the role of context (whether or not an explicit

context is provided). This view is grounded in the dynamic semantic/pragmatic approach to meaning, which analyzes meaning at a dialogue/discourse level (e.g. Ginzburg, 2012; Lewis, 1979; Roberts, 2012; Sperber & Wilson, 1986; Stalnaker, 1978). In this chapter, I will first introduce the dynamic semantic/ pragmatic approach by comparing language use to a game (2.1). I will then discuss what is in the context (2.2), and how utterance interpretation updates the context (2.3). In the last section (2.4), I will present the dynamic pragmatic account of negation processing.

2.1   Dynamic semantic/ pragmatic approach to meaning

Natural language use is interactive. Identifying and updating contextual information play a central role in communication. To understand the dynamic approach to meaning, it is useful to think of language use as a game, an analogy used by many scholars (Wittgenstein, 1953; Lewis, 1979; Roberts, 2012; Ginzburg, 2012). In a game, participants interact according to specific rules to achieve goals. The three key elements - goals, rules and interaction - can be seen in language use.

Firstly, **goals:** we engage in a conversation to achieve general and specific goals. Stalnaker (1978) proposes that the general and primary goal is to discover and share with other participants information about the world. In a conversation, we often have specific goals or domain goals (Roberts, 2004), such as buying a train ticket or getting directions. In all cases, information is exchanged and our beliefs and knowledge about the world are updated after a "game session".

Secondly, **rules**: broadly speaking, rules of a language game can be either conventional or conversational. Conventional rules come from our linguistic knowledge. We select tokens that have public meanings, and form utterances that follow the syntactic rules of the language. Conversational rules are less clearly defined. They are non-linguistic constraints or preferences for certain communicative strategies. An example is Gricean conversational maxims (Quality, Quantity, Relation and Manner) (Grice, 1975). For example, if I want to communicate the information that the shop is open, both "the shop is open" and "it is not the case that the shop is closed" follow conventional rules. However, the first but not the second version follows the conversational maxim of Manner. Relevance theory (Sperber & Wilson, 1986) explains language users' strategies by assuming that we choose the optimal interpretation, one that maximizes the cognitive payoff of any communicative act with the least effort.

Lastly, **interaction**: language use is interactive. In a conversation, participants take turns to perform their moves. The moves can be linguistic utterances, such as questions and assertions, or non-linguistic actions, such as passing someone a salt grinder after hearing "can you pass me the salt?"

The dynamic approach likens language use to a game, where utterance meaning is dependent on the dynamically changing context. As we are interested in sentence processing, we will focus on how utterances are interpreted in this framework. To do that, let's take a closer look at how context and utterances interact with each other. In the game analogy, Lewis (1979) compared language use to a baseball game, and pointed out that context can be seen as the dynamically changing scoreboard. The

baseball scoreboard (or a box score) is a "septuple of numbers" (Lewis, 1979: 342).

Different moves (e.g. a single hit or a homerun) result in different changes on the

scoreboard. At any given time, the information on the scoreboard tells us the number

of moves so far of each type and what upcoming moves are allowed. Similarly, in the

language game, the context is a structured set of entities that dynamically change

with each utterance. Utterance interpretation results in an update of the context.

Some even go as far as to say that the meaning of an utterance is its context change

potential (I Heim, 1983; Kamp, 1981). In the next section, I will discuss the elements

in context.

2.2   Context

Context is the information state relative to a conversation as it is represented in the

minds of the conversational participants. Context is frequently shared. However, the

information state of a participant may also contain private information that affects

language production or comprehension. Different theories propose different models

of how context is represented. Some theories focus on just the public context (e.g.

Roberts 1996), where all participants have the same representation of its dynamic

content. Some (e.g. Lewis 1979) suggest that in addition to the public context,

participants each present their own distinct private context. Information from both

the public and private contexts can influence language use. Yet others (e.g.

Ginzburg, 2012) argue that each participant represents their own versions of the

public and private information. For the most part, different versions of the public

context are identical. However, differences can arise due to the speaker/addressee

difference: a speaker is committed to knowing what her utterance means, while an addressee does not have such commitment. For my purposes, I will ignore the theoretical differences in context representation, and focus on the public content of context.

What then is in the context? Let's first use an example to see what context does to utterance interpretation. Suppose you are in a group meeting in London when a colleague rushes in and says "I'm so sorry. The Jubilee line was delayed again". What does she mean? Roughly, I understand that the speaker is sorry that she is late for the meeting. The reason she is late is because she took the Jubilee line in the London Underground and the line was delayed. In addition, the speaker presupposes two pieces of background information: 1. there has been a recent and salient occasion when the Jubilee line was delayed which made her late for work or a meeting, and 2. the hearers know what "the Jubilee line" refers to. If for example you have no knowledge of the speaker's past experience or what "the Jubilee line" is, you can infer her assumption 1, and guess that "the Jubilee line" refers to a distinctive part of the London transport system. How did I get all this information from hearing her utterance? My knowledge of the English language allows me to understand the linguistically coded meaning of the strings above. The rest of the content is provided by the interaction between the utterance and context. What did the context do?

Referent assignment: "I" refers to the speaker.

Saturation (Recanati 1993): "I am sorry (for being late for the meeting)".

Presuppositions: the speaker assumes two pieces of background information that the hearers have, because of the strings "the Jubilee line" and "again".

Source of Relevance: the second utterance (the Jubilee line was delayed again) is related to the first (I'm sorry) in that it is to explain why the speaker was late (and not why she was sorry).

So context helps us determine the proposition expressed (referent assignment and saturation); it provides background information and the relevance of the speaker's utterance, so that the utterance is felicitous. What does the context contain that allows it to do such things? At any given point in a conversation, the context should contain not only information that is taken for granted, but also the likely sources of relevance for the most recent utterance. The content of the context can be captured by different theoretical frameworks. Some (e.g. Ginzburg, 2012; Lewis, 1979; Roberts, 2004) propose that context is a structured set of sub-elements, one of which is a set of un-answered questions (Questions Under Discussion) that represent the sources of relevance. For others, for example Relevance Theory (Sperber & Wilson, 1986), the likely sources of relevance are mutually manifest sets of assumptions that make the proposition being expressed relevant. Here I present a framework of context based on the first view (Ginzburg, 2012; Roberts, 2004) to discuss sources of relevance[6]. At any given point in a conversation, the context contains at least three components: the set of propositions that are taken to be true (akin to Stalnaker's (1974) notion of the common ground), the moves that have taken place, and the set

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[6] This is not an argument against alternative frameworks such as Relevance Theory. What is important is that the source of relevance for a given utterance must be part of the discourse context. However, the nature of the representation of the source of relevance remains a topic for future research.

of unresolved questions under discussion or the QUD stack (Ginzburg, 2012; Roberts, 2012)[7].

2.2.1 Stalnakerean common ground

The first element in the context is the set of propositions that are publically taken to be true, akin to Stalnaker's notion of the common ground. The content may come from general beliefs that are already in participants' belief boxes, or have entered the context by previous utterances. This element is closely linked to the notion of "pragmatic presuppositions" or "speaker presuppositions" by Stalnaker (1974), which differentiates from the "semantic presuppositions" or "utterance presuppositions". Pragmatic presuppositions are what a speaker assumes to be background beliefs at any given point. Stalnaker (2002) describes it as the "propositional attitude of the speaker". Semantic presuppositions focus on the utterances[8]. They refer to the set of propositions that are taken for granted for an utterance to be felicitous (Karttunen, 1974; Lewis, 1979; Stalnaker, 1973, 1998; von Fintel, 2004 among others). Pragmatic/speaker presuppositions cannot be cancelled (because they are the speaker's beliefs) while semantic/ utterance presuppositions can. To illustrate, look at the famous example "the King of France is not bald". The utterance presupposes that a unique King of France exists. However, a speaker need

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[7] It should also contain a set of salient discourse referents, as proposed by Discourse Representation Theory (Kamp, 1981). In our late-for-meeting example, this element provides us with the salient referent for "I" and "the Jubilee line".

[8] Note that I make no claim about whether "semantic presuppositions" in negative sentences are semantically or pragmatically derived. Here "semantic" presuppositions are simply presuppositions associated with an utterance, which are often but not always part of the speaker's beliefs when she makes the utterance.

not presuppose that the King of France exists, as she can say "the King of France is not bald because there is no King of France".

2.2.2 Moves

The second element of context is the set of moves made up to a given point. Unlike the Stalnakerean common ground, which is traditionally seen as an unordered set, the set of moves is ordered according to the sequence in which the moves are performed[9] (Roberts, 2004). Note that even if an interlocutor rejects an utterance, the fact that the utterance was made still enters the context. For example, if I utter "whales are a type of fish" and you tell me that I was wrong, the fact that I uttered this sentence enters the context but not the belief that whales are a type of fish.

Moves can be functionally divided into set-up moves and pay-off moves (Carlson, 1983; Roberts, 2012). The former are questions[10] and the latter assertions[11]. The relation between questions and assertions plays an important role in the functional structure of a dialogue (ibid). Questions signal plans and specific goals of a dialogue,

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[9] This is a theoretical idealisation. In practice, evidence suggest that the representation of the linguistic forms of utterances and of their order decay quickly after an utterance is made (e.g. Sachs, 1967). See Fletcher (1994) for a review. Ginzburg (2012) argues for a prominent representation of the Latest Move.

[10] There is no consensus on what a question is semantically. Partition views believe that a question denotes the set of possible answers or exhaustive answers (Groenendijk & Stokhof, 1984; Hamblin, 1973). In this view, positive and negative polar questions are semantically identical, i.e. the question "*whether p*" and "*whether ¬p*" both denote {*p, ¬p*}. On the other hand, propositional abstraction views (Ginzburg & Sag, 2000; Hausser, 1983) suggest that a question denotes an abstract of its answers. For example, the question "who solved the problem" denotes the function f(x) such that x solves the problem. By these views, positive and negative polar questions have distinct semantic denotations, as they are each abstracts of positive and negative propositions, i.e. "*whether p*" is an abstract over *p*, while the negative polar question "*whether ¬p*" is an abstract over *¬p.* There is evidence in answer particles to positive and negative polar questions which supports a semantic analysis that differentiates positive and negative polar questions (e.g. Farkas & Bruce, 2009). For my account, I use the propositional abstraction analysis, and distinguish positive and negative polar questions semantically.

[11] Clearly there are types of utterances other than questions and assertions, such as imperatives, greetings and parting pairs. For simplicity, we will focus on just questions and assertions.

and assertions serve to realise these goals. When a question is accepted[12] by the participants, they are committed to answering it. Very often, questions are implicit, and are pragmatically retrieved on the basis of linguistic or non-linguistic cues. For example, in the "late for meeting" example, the hearers can retrieve the implicit question *why the speaker was late* for the utterance "the Jubilee line was delayed again" based on an expectation about social norms in this situation. It is clear that the representation of questions in discourse (explicit and implicit) cannot be handled entirely by the Stalnakean common ground and the set of moves. Questions are not propositions and therefore cannot be taken to be true. The set of Moves cannot distinguish answered and unanswered questions, and it doesn't relate assertions to questions, i.e. what question a particular assertion is relevant to. This shortfall brings us to the third element of context: the set of Questions Under Discussion (QUD).

2.2.3   QUD

The notion of Question Under Discussion was proposed by Carlson (1983) and elaborated by scholars such as Roberts (1996) and Ginzburg (1996, 2012). The underlying idea is that discourses are functionally structured by question/answer relations, which is also the source of discourse coherence (Kehler, 2012). At any given point, there is a set of unanswered questions or the QUD stack (Ginzburg, 2012). The top item in this stack is the *immediate* QUD or simply the QUD. QUD tells you what the discourse is 'about' at a given point and "where the discourse is going" (Roberts, 2012). This is because the upcoming move has to provide at least a

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[12] Neither Roberts (2004, 2012) nor Ginzburg (2012) gave a clear definition of what it is to "accept" a question. Roughly, if a question is not rejected (by explicitly rejecting or changing the topic), it is accepted.

partial answer to the QUD[13]. An assertion is coherent if it provides a (partial) answer to the QUD. In our previous example, the utterance "the Jubilee line was delayed" answers the implicit QUD "why is the speaker late"? To understand the coherence relations among utterances, we routinely infer and accommodate the QUD to which an assertion is relevant. When there is no specific domain question, the QUD is the general goal proposed by Stalnaker (1978): to discover "the way things are". This explains why discourse-initial utterances that provide "all new" information can be felicitous.

We have seen briefly what context contains in a dynamic approach. Now I will discuss what utterance interpretation does to the context.

2.3   Utterance interpretation

Just like a move in baseball changes the game scoreboard, the interpretation of a move in conversation updates the context. The meaning of an utterance is its context change potential (I Heim, 1983). What exactly gets updated by utterance interpretation? Roberts (2012) argues that the update of any move involves two aspects: its proffered content and its presupposed content[14]. The proffered content of an utterance is roughly its semantic meaning. The presupposed content, for Roberts,

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[13] I will not go into the details of what constitutes "answerhood", but an answer need not be direct. For example, a question can be answered by another question, the conversational implicature of an assertion, or even "I don't know" (see Roberts, 2012 and Ginzburg, 2012 for discussions). Also, in natural conversations, interlocutors can engage in several rounds of clarifications before an answer is provided to the original QUD, or question the intention of the original QUD (e.g. why are you asking me this?). Such moves are relevant to the QUD but they don't constitute answers. See Ginzburg (2010) for a detailed analysis of dialogue relevance.
[14] It is not clear where conversational implicatures go in this model. It could be argued that at least foregrounded implicatures that contribute heavily to speakers' meaning are a third component of utterance content.

"constrains the types of context in which it may be felicitously uttered" (Roberts, 2012:9). The presupposed content contains the presuppositions of the utterance, as well as its source of relevance or QUD. The interpretation of an utterance can update all three elements of the context.

Questions are set-up moves. They indicate the speakers' domain goals, and constrain the direction for the upcoming discourse. For the purpose of this story, I will not discuss the context update of questions. Here I assume a simplified view that a question, when accepted, becomes the QUD.

Assertions are pay-off moves, so their interpretation differs from that of questions in that we need to know what they are paying off. The interpretation of an assertion updates the context not only by the proffered content, but also by its presuppositions and its source of relevance, i.e. QUD. We check if the presuppositions are part of the common ground and check if the assertion is relevant to the QUD. If so, the utterance is felicitous. If not, very often, we can still integrate the utterance into the discourse successfully. This is because we can retrieve the presuppositions and QUD using linguistic or non-linguistic cues, and *accommodate* them into the context (I will discuss *accommodation* in more detail in 2.4). I argue that presupposition accommodation and QUD accommodation are similar processes in terms of how context is updated procedurally. However they are distinct because different contextual elements are updated and because they affect upcoming discourse in different ways. In other words, I argue that distinct contextual elements are updated using the same "accommodation" process.

Presupposition and its accommodation has been a central topic in pragmatics, which has been studied intensively for over forty years. On the other hand, while the importance of QUD has risen in popularity in the last twenty to thirty years due to the development of dynamic semantics and pragmatics, the attention QUD accommodation has received in research is minimal. In the next two sections, I will first discuss presupposition accommodation, and then QUD accommodation.

2.3.1 Presupposition accommodation

The presuppositions of an utterance are background beliefs that are taken for granted. We recognize the presuppositions of an utterance through certain "triggers", such as aspectual verbs (e.g. *stop*, *continue*) and definite descriptions (see Levinson, 1983: chapter 4 for a detailed discussion of presupposition triggers) For an assertion to update the common ground, its presuppositions must be part of the context. For example, the proffered content of "my cat is sick" can be updated only if the belief that I have a cat is in the common ground. When this requirement is not met, you can *accommodate* the presupposition that I have cat, and interpret the assertion successfully.

What then is presupposition accommodation? Following von Fintel (2008), I will debunk two misconceptions. First, timing: do presuppositions need to be part of the context prior to the utterance being made? No. If that was the case, accommodation would not be possible. Also it doesn't happen before the utterance is processed. Presuppositions only need to be accommodated before the informational state update by the proffered content can take place, not before the utterance is made. Second,

mechanism: is accommodation pretence? The classic treatment of presupposition accommodation involves acting-as-if or pretence (e.g. Lewis, 1979; Stalnaker, 1978). If the hearer detects that the presuppositions of an utterance are not part of the context, and has no dispute over their truth, she can behave as if that information has been in the context all along. Thomason (1990: 342) points out that "acting as if we don't have a flat tire won't repair the flat; acting as if we know the way to our destination won't get us there", acting as if the presupposition has been in the context all along doesn't explain how the context is updated by presupposition accommodation. Gauker (2008) points out that informative presuppositions presents a serious problem for the pretence story. See this example, the utterance "do you know that John got married?" presupposes that John got married, which must be in the context for the utterance to be felicitous. If in fact you didn't know that before I asked you, and pretend that you knew it all along due to presupposition accommodation, you should therefore answer me "yes"?

So presupposition accommodation is not pretence, and it need not happen prior to an utterance being made. What is it then? von Fintel (2008:1) describes presupposition accommodation as "the process by which the context is adjusted quietly and without fuss to accept the utterance of a sentence that imposes certain requirements on the context in which it is processed". He proposes that utterance interpretation affects the context in two steps: Step 1: the fact that the utterance was made enters the context. Participants immediately draw inferences about the contextual requirement based on that fact, and adjust the context accordingly. Step 2: the proffered content is added to the context. Presupposition accommodation happens in step 1. When hearing an

utterance with presupposition triggers, participants draw inferences about the presuppositions that must be part of the context. If they are not, participants first update the context with these presuppositions, and only then with the proffered content of the utterance. Note that these two steps are procedural only in terms of order the context update. It does not mean that the proffered content is only computed after the presupposition is accommodated. Rather, presupposition accommodation can and should happen *incrementally*. That is, certain presuppositions can be accommodated as soon as they are identified, and potentially before the utterance is finished. For example, upon hearing "my sister …", the hearer can update that the speaker has a sister before the utterance is finished.

2.3.2   QUD accommodation

I argue that QUD accommodation happens in a similar way to presupposition accommodation. When the hearer interprets an assertion, she checks if there is an explicit QUD to which the assertion is relevant. If not, she can retrieve and accommodate the prominent QUD using linguistic and/or non-linguistic cues, before updating the proffered content of the utterance. An example of a non-linguistic cue is what Ginzburg (2010, 2012) calls "genre specificity", where an assertion answers a QUD specific to an activity or genre type. For example, if a customer walks into a coffee shop and says "I'd like a flat white", the hearer can infer that the utterance is relevant to the implicit question "what coffee would you like". An example of a linguistic cue is prosodic focus. In English, prosodic focus in an assertion constrains the kinds of questions it can answer (Roberts, 2012). The constituent with focus is new information in the utterance, and thus it was unknown in the QUD. The

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constituents without focus are old information, put forward by the QUD. When the

QUD is not explicitly realised, prosodic focus acts as a cue for retrieving the

prominent QUD. For example, on hearing "[JOHN]$_f$ invited Mary for dinner." (here

"John" receives prosodic focus), the hearer can retrieve the QUD "who invited Mary

for dinner?" based on the constituent in focus. The hearer will first update the QUD

stack with the question, and then enter the proffered content into her belief box.

2.4   Dynamic pragmatic account of negation processing

I argue that negation is a cue for retrieving a prominent positive QUD. Without other

cues, the most prominent QUD for a negative sentence ¬p is *whether p*. For example,

the QUD for "the door is not open" is whether the positive counterpart is true,

namely "whether the door is open". When this question is not explicitly realised,

negation triggers us to accommodate a positive QUD. Like presupposition

accommodation, QUD accommodation happens before the proffered content of the

sentence can update the context. This two-step context update captures the intuition

that QUD or source of relevance of an assertion is background information.

This account marries well with the contextual approach to negation, which observes

that negative sentences often seem less felicitous out-of-the-blue than positive

sentences. This is likely due to what negation is most frequently used for. A corpus

study by Tottie (1991) shows that the two main functions of negation are rejection

and denial. Rejection can be seen in negative responses to an offer and denials are

used to reverse the truth of a proposition. Denials can be either explicit or implicit.

Explicit denial is a response to an explicitly asserted proposition, like the previous

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example. In case of implicit denial, the proposition to be denied is inferred from the context. Implicit denial is very frequent. In their sample of 427 cases of negation in spoken English, 286 (67%) are implicit denial (Tottie, 1991: 35).

I argue that the accommodation of a positive QUD triggered by negation is due to its most frequent uses, therefore it is not hard-wired as part of the semantic property of negation. There is growing research on the probabilistic nature of language processing (cf Chater & Manning, 2006; Crocker & Brants, 2000). It is highly plausible that QUD retrieval is probabilistic. Language users build a frequency based model of the prominent QUDs associated with negative sentences, and the QUD for a negative sentence is probabilistically retrieved, and should thus be sensitive to other cues and other factors such as word frequency of the predicate. For example, cleft structure signals the old and new information in the sentence, and is a cue for QUD. "It is John who hasn't finished his homework" has the QUD of "who hasn't finished their homework". In this case, the negative sentence has a negative QUD. In addition, word frequency can play a role in QUD retrieval. For example, if I want to answer the question "How are you feeling?" I have the choice of "I am happy", "I am not happy", "I am sad" or "I am not sad". As "happy" (0.0129% based on British National Corpus) is more frequent than "sad" (0.0036% BNC), the difference in processing effort between "I am not happy" and "I am sad" is smaller than the difference between "I am happy" and "I am not sad". So the utterance of "I am not sad" strongly projects the prominent QUD of "are you sad", while "I am not happy" can felicitously answer both the question of "Are you happy?" or "How are you feeling?".

Can negation triggered QUD accommodation be unified with prosodic focus triggered QUD accommodation? Not entirely. Hedberg & Sosa (2003) studied the intonation of negative sentences, and found that the negative morpheme or auxiliary is almost always marked with a high pitch accent, except when negation is contracted with the auxiliary "do". Therefore, when negation is accented, the QUD can be retrieved through prosodic focus. When it is not, and when no other constituent is focused, negation itself acts as a QUD cue. The same thing applies to reading context-less negative sentences.

2.4.1 What is accommodated is a question rather than a proposition

It has been proposed that negation denies positive presuppositions. Wason (1959, 1961) says that the function of negation is to "deny presuppositions rather than to assert new information". Similar ideas have been proposed by Givón (1978) and Evans, Clibbens, & Rood (1996). Levine & Hagaman (2008) propose that whenever negation is encountered, "an inferential process is invoked, one that searches for a presupposition to cancel or deny". If the presupposition is explicit or easily inferred in the prior discourse, then negation is understood without much difficulty, because the utterance violates Gricean maxims (Grice, 1975) and comprehenders must draw a pragmatic inference as to why negation was used. If this is the case, then negation can trigger the accommodation of a positive proposition rather than the QUD.

This account is problematic as presuppositions are what are taken to be TRUE for a given utterance to be felicitous. Clearly, the sentence "the door isn't open" does NOT presuppose that "the door is open" is true. If negation triggers comprehenders

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to "search for presuppositions to cancel or deny", where does this presupposition come from? Not all negative sentences imply a background positive expectation. For example, if a friend asks me how I feel, I can say "I'm not happy", without there being any expectation of me being happy.

I argue that negation triggers the accommodation of a positive QUD, rather than a positive presupposition. Look at this example:

19) (Broken vase pieces on the floor): *Tommy turns and looks me in the eyes, and with the straightest face an eight-year-old can make, he says, "I didn't do it." "I didn't ask if you did, I just ask what happened," I correct him.* (Internet source)

20) *A: What happens if you switch to the Twenty Eleven theme?*

B: I don't need Twenty Eleven theme.

A: I didn't ask if you did. (Internet source)

21) (*Discussing* fashion models)

A: They aren't gay lol…

B: I didn't ask if she is gay and even didn't think of it. (Internet source)

In example (19), Tommy's utterance "I didn't do it" allows the hearer to infer and accommodate the QUD "whether Tommy did it (break the vase)", illustrated by the response "I didn't ask if you did", which is only coherent if a question was accommodated, rather than the positive presupposition "you broke the vase". Similar analysis applies to the other examples.

Also, negative sentences can be used with "in case you wonder" or "before you ask":

22) (twitter entry) "*Before you ask, I didn't write this*" (followed by a link to an article).

We can rephrase this sentence as "in case you wonder, I didn't write this". Here "in case you wonder" and "before you ask" contains null complement anaphora that can only be satisfied by a question, and in this case, by the accommodated QUD *whether I write this*. If negation triggered the accommodation of a proposition, the above sentence would be ungrammatical.

If negation triggers the accommodation of a QUD where the truth of the positive counterpart is at issue, why do we intuitively feel that very often there is a positive expectation in the background? For example, if I say "this morning my train wasn't late", you can infer that my trains are normally or often late. How do such positive implicatures arise? They can be inferred through the accommodated QUD. Polar questions are biased (Sudo, 2013). If upon seeing you, I ask "have you put on weight?", you infer that I have some evidence suggesting that you have put on weight, but perhaps not strong enough to warrant a belief. You can question the evidence by asking "what make you think that?". Stivers & Enfield (2009) report that among answers to polar questions, there is a bias towards confirmation. Confirmations are faster than rejections across many languages. Also, there is a greater proportion of confirmations than rejections (ranging from 70% in Danish to 89% in Yeli-Dnye). When a polar question *whether p* is at issue, there is a good chance that that p is true and therefore relevant. For our train example, we

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accommodate that *whether your train was late* is at issue. The fact that this question is at issue allows us to infer that the positive proposition "the speaker's train was late" was expected to be true, and thus infer that normally the speaker's train is late.

2.4.2 Positive versus Negative assertions

What are the differences in the context change potential of positive assertions and negative assertions? Ginzburg (2012) suggest that the positive assertion p can update the context in two ways: either add the belief of *p,* or give rise to the discussion of *whether p.* This is supported by a corpus study by Enfield, Brown, and de Ruiter (2009), who found that across languages, it is common for polar questions to have no linguistic marking (including intonation), i.e. an assertion can function as a polar question if it is clear that the speaker has a lower level of commitment to knowledge than the speaker.

If a positive proposition *p* can give rise to the discussion of *whether p,* and a negative proposition ¬*p* triggers the accommodation of *whether p*, do positive and negative sentences have the same effect on context apart from their proffered content? No. With a positive proposition, the choice of discussion of *whether p* arises AFTER the context update of p. This effect is on the oncoming discourse. On the other hand, a negative proposition triggers the accommodation of *whether p*, which happens BEFORE the context update of ¬*p*. This effect is on the background information.

Like a positive assertion, a negative assertion ¬*p* can give rise to the upcoming discussion of *whether* ¬*p*. This is clear in languages such as Japanese and Chinese

where polarity particles are only used to signal whether the response is confirmation or denial (relative polarity). When answering a negative polar question, the answer polarity particle does not match the polarity of the answer itself (Pope, 1976). For example, in Chinese, the question of "does John not drink" can be answered by the Chinese equivalents of "yes, he doesn't", or "no, he does". In other languages, such as in English, polarity particles as answers to negative polar questions are ambiguous. They can either have absolute polarity (match the polarity of the answer proposition), or have relative polarity. After a negative assertion in Chinese, such as "Yuehan bu he jiu" (John doesn't drink), if the hearer wants to contradict, she has to say "bu, ta he" (no, he drinks), which can only be an answer to the negative polar question *whether ¬p*, rather than the positive polar question *whether p*. This shows that a negative assertion ¬p can give rise to the upcoming discussion of *whether ¬p*.

Positive assertions can give rise to QUD accommodation of *whether ¬p* if the auxiliary is accented. For example, without context, the assertion "I DID call my mum" triggers the accommodation of the question of if the speaker didn't call her mum. Intuitively, without context, this utterance is less felicitous than "I called my mum".

2.4.3   Processing negative sentences out of context

Negation is a cue for a positive QUD, which is accommodated if it is not explicit in the context. I argue that this process is automatic: it happens when we engage in a conversation, AND when we participate in a psycholinguistic experiment. Sentence comprehension can NEVER be independent from context. When participants read

negative sentences without context, they retrieve the prominent QUD and accommodate it, even when there is no explicit speaker. As we have seen in the previous chapter, many studies found that the representation of the positive argument is involved in negation processing. This is not because negation is processed by first representing the positive argument and then rejecting it, rather, it is due to QUD accommodation. This process explains at least in part why negative sentences are more difficult to process than their positive counterparts when there is no contextual support. The representation of the positive QUD and the negative sentence meaning are incongruent with each other. Studies show that representing conflicting events is costly (Hindy, Solomon, Altmann, & Thompson-Schill, 2013). In comparison, a positive proposition (e.g. the shop is open) can answer the QUD of "is the shop open", "what information do you have about the shop", or the general question of "how things are". In any case, the representation of these QUD not incongruent with the sentence representation. This account predicts that if a positive sentence has a negative QUD, as in "I DID call my mum", they are more difficult to process than ones that have a positive QUD "I called my mum".

A welcome consequence of this explanation is that the meaning of negation can be incorporated incrementally, rather than after the positive argument is first processed. This prediction fits nicely with the growing evidence for incremental sentence processing. Not only should negation be incorporated incrementally, I also argue that QUD retrieval and accommodation can happen incrementally. For example, if you are a waiter in a coffee shop, as soon as a customer utters "I'd like...", you can construct the QUD of "what would you like". Upon hearing an utterance where an

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initial constituent is focused, such as "MARY invited ...", you know that "Mary" is new information and the rest of the utterance gives old information, and you can start constructing the QUD of "who invited...". Similarly, upon hearing a negative sentence such as "John hasn't ...", you can infer that the prominent QUD is "whether John has...". This idea fits with the findings that the representation of the positive counterpart happens in the early stage of negation processing.

2.5   Summary

In this chapter, I have argued for a dynamic pragmatic account of negation processing. Utterance interpretation updates the context with not just the proffered meaning, but also pragmatically retrieved content, such as presuppositions and QUD. These elements determine the felicity of the utterance. Unless they are part of the context, the proffered content cannot be updated. When presuppositions or QUD is not in the context, hearers can retrieve and accommodate them using linguistic or non-linguistic cues. Negation is one such cue.

Negative sentences are most frequently used when a positive QUD is at issue. When processing $\neg p$ without context, participants retrieve a positive QUD of *whether p*. QUD accommodation is automatic and incremental. This account explains why the representation of the positive counterpart is often involved in negation processing, why negation is more difficult to process than their positive counterpart when sentences are presented out of context, and why contextual support can reduce or eliminate negation associated cost.

In the next three chapters, I present three series of experiments to test the dynamic pragmatic account of negation processing.

Chapter 3   Negation and the representation of the positive counterpart – a probe recognition study

In chapter 1, we saw that processing negative sentences often involves the representation of the positive counterpart. Rejection accounts propose that such a representation is the first step of negation processing. Specifically, the two-step simulation account (Kaup, Zwaan, et al., 2007) proposes that negation is processed with two sequential simulations: first a simulation of the positive counterpart, and then a simulation of the actual state of affairs. In chapter 2, I argued that the positive counterpart is often represented, not as the first step of negation processing, but due to the accommodation of a positive QUD. This chapter presents three experiments testing the two-step simulation account and the dynamic pragmatic account.

3.1   Introduction

A study by Zwaan, Stanfield, and Yaxley (2002) found that participants mentally represent the shapes of objects described by the sentence. In the experiment, participants read sentences such as "*The ranger saw an eagle in the sky/nest"* and afterwards saw a picture of the object noun (an eagle) that either matched or mismatched the implied shape of the item. For "eagle in the sky", a matching picture would be a bird with stretched wings, and a mismatching picture would be a resting bird. Participants were asked to respond whether the item in the picture (eagle) was mentioned in the sentence. Their results showed that reaction times were faster when the picture matched the implied shape than when it mismatched the shape. They

concluded from the result that the comprehenders construct mental simulations of situations described in the sentence.

Kaup, Yaxley, Madden, Zwaan, & Lüdtke (2007) used this paradigm to study representations during negation processing. Participants were asked to read positive or negative sentences (e.g. The bird is /isn't in the air), and were shown a picture that matched or mismatched the sentence meaning at certain inter-stimulus intervals (ISI) after reading. Replicating the results of Zwaan et al. (2002), participants responded faster to a matching picture than a mismatching picture after reading a positive sentence. However, for negative sentences such as, "The bird isn't in the air", the reaction time (RT) pattern reversed at 250ms ISI. Although the sentence implies that the bird is not flying, participants responded faster to a flying bird (mismatch) than a resting bird (match), as if negation was ignored. However, after a longer interval (1500 ISI), participants responded faster to a matching picture to a mismatching picture for both positive and negative sentences. This study shows that when processing a negative sentence, its positive counterpart is represented at an early stage.

Kaup and colleagues (2006, 2007) propose that the two stages of simulations are a result of the mechanism of negation processing. The underlying theory is that the creation of non-linguistic mental simulations is a central component of language comprehension. These simulations are non-linguistic in nature, and are grounded in perception and action (Barsalou, 1999; Zwaan, 2004). During sentence processing, comprehenders construct simulations of situations described in the sentence, and

these simulations allow us to "experience the world by proxy" (Johnson-Laird, 1983: 471, cited in Kaup, Zwaan, et al., 2007). Zwaan (2004) proposes the "Immersed Experiencer Framework", which states that experiential simulation is the only meaning-related representation in language comprehension. All aspects of language interpretation are simulated, including abstract symbols and operators. Based on this view, Kaup and colleagues (2006; 2007) propose a "rejection mechanism" that allows for the experiential simulation of the content negative sentences. The negated content –the positive argument- is represented separately in an 'auxiliary representational system' and prior to any representation of a state of affairs consistent with the negated sentence (Kaup, Yaxley et al., 2007: 987; Kaup et al., 2006: 1046). Specifically, their model states that negation is processed with a "two-step simulation": the negated information is first simulated and then 'rejected', a process that juxtaposes a simulation of the actual state of affairs with the representation of the state of affairs consistent with the positive argument of negation. The first step is faster or omitted if the negated information has already been mentioned or is strongly inferred. It is proposed that this two-stage process occurs so that the negated content can be 'rejected'.

This model can explain why the positive counterpart is represented during negation processing, why negation takes longer to process than affirmative sentences, and that context affects the ease of negation processing. However, as I pointed out in Chapter 1, it cannot explain all the empirical results. Many studies found that representing the positive counterpart is not mandatory (e.g. Dale & Duran, 2011 experiment 2 & 3; Nieuwland, Ditman, & Kuperberg, 2010; Tettamanti et al., 2008). In response to

some of these findings, Kaup et al. (2007) proposed that if the positive counterpart is explicitly mentioned or strongly implied by the prior discourse context, it need not be represented during the processing of the negative sentence. However, some contexts in the above mentioned studies do not mention or strongly imply the positive counterpart. For example, Nieuwland and Kuperberg (2008) found that with the context "with proper equipment", the false affirmative sentence "scuba-diving is very dangerous and often good fun" elicit a much stronger N400 than the true negative sentence "scuba-diving isn't very dangerous and often good fun" (time-locked to the critical word "dangerous"), suggesting that the positive counterpart (the false affirmative) was not first considered when processing the true negative sentence. This context ("with proper equipment") does not strongly imply that the positive counterpart of the negative sentence was expected. In addition, rejection accounts suggest that the meaning of negation cannot be incrementally incorporated. This implication seems at odds with abundant evidence for incremental language processing. I argue that the negated information has been found to be simulated in these previous studies, not because it is the first step in the process of representing the content of the negated sentence, but because negation can trigger the accommodation of a positive QUD.

3.2   Negation, QUD, and the representation of the positive counterpart

Is the representation of the positive counterpart necessarily a result of processing the linguistically coded content? As argued in Chapter 2, utterance interpretation should not only involve accessing the linguistically coded content, but also involve inferring

contextual information such as sources of relevance for the utterance. Studies (e.g. Brown-Schmidt, Gunlogson, & Tanenhaus, 2008) have shown that both processes can and do occur in incremental processing. Thus, when we collect time-sensitive data from comprehension tasks, we should be aware that our results may not only be the product of a process of representing an interpretation of the sentence, but also a process of representing how the content relates to the broader discourse context.

As argued in Chapter 2, discourse context includes not only facts that are taken for granted, but also the sources of relevance for a given utterance, or the Questions Under Discussion. Every assertion addresses one prominent QUD. Importantly, the relative prominence of QUDs changes as discourse unfolds and may be adjusted via the mechanism of accommodation, which retrospectively updates the QUD stack.

I argue that the design of psycholinguistic experiments should take into account this dimension of the pragmatics of discourse comprehension. When faced with an experimental sentence in isolation, and no other information, the prediction is that participants will use cues in the linguistic input to project likely QUDs. In the case of negative experimental items, in the absence of any other contextual stimuli, participants use negation as a cue and project a positive question as the most likely prominent QUD. That is, given an item like, 'The bird is not in the air', participants will tend to project the positive QUD *whether the bird is in the air*. It follows then that the effect found in Kaup, Yaxley, et al.(2007) mentioned above could be an artefact of the task: the finding that the positive argument of negation is first simulated could be the result of accommodating a positive QUD rather than the

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result of a necessary part of the process of interpreting a negative sentence. Thus, according to the two step simulation account, representing the positive argument is a necessary stage in processing negation, while on the dynamic pragmatic account, it is not necessary as there are possible contexts where a negative QUD is being addressed.

The following three experiments are designed to differentiate these two accounts (two-step simulation processing *versus* pragmatic accommodation). In experiment 1, I use a similar paradigm as in Kaup et al. (2007), but tested simple negative sentences and cleft sentences with negative clauses. For example, "Mike didn't iron his shirt" and "It was Mike who didn't iron his shirt", respectively. Participants saw an image of an ironed shirt or a crumpled shirt after reading either sentence, and had to decide if the item (shirt) has been mentioned in the preceding sentence.

In English, the most common form of cleft sentence is "it-cleft", which has the form, *it + be + X + subordinate clause*. For example, "it is John who didn't iron his shirt". Clefts are known to be presupposition triggers (Levinson, 1983). The above sentence presupposes "someone didn't iron their shirt". Cleft structure also constrains the most likely QUD. In this example, the clefted constituent ("John") is the only constituent in focus, and the rest (didn't iron one's shirt) is old information. The construction thus serves as a cue for the prominent QUD *who didn't iron their shirt*. Note that the example question is negative. I predict that when the stimulus is a simple negative sentence like "John didn't iron his shirt", participants will respond faster to a mismatching image (smooth shirt) than a matching image (crumpled

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shirt). However when the stimulus is a cleft negative sentence, like "it is John who didn't iron his shirt", we will see a reversed pattern. On the other hand, the two-step stimulation account should predict the same pattern for both simple and cleft negative sentences, since both sentences express the same negative proposition. As I understand it, their two-step model predicts that negation is treated in the same way for simple and cleft sentences: in order to represent the content of the negative sentence, the positive argument needs to be first represented and then rejected.

Experiment 2 serves as a follow-up to experiment 1, testing the proposed explanation to the difference between simple and cleft negative sentences. Experiment 3 moves away from negative sentences, and test QUD accommodation positive sentences which have a prominent negative QUD.

3.3 Experiment 1

3.3.1 Method

Participants

Forty native English speakers from the undergraduate population of University College London were paid to participate in the study.

Materials and Design

Twenty-eight experimental items were constructed, pairing a single sentence with a colour picture. All experimental sentences included a negative operator (e.g. *didn't*) and could either be clefted, as in, *It was [Character] who didn't VP*, or non-cleft, as

in, *[Character] didn't VP*. VP describes or implies the physical state of an object, which in this negative construct implies a shape that is at odds with that implied by the alternative affirmative construct. For example, "Jane didn't cook the spaghetti" implies that the spaghetti is uncooked, while its alternative affirmative form would imply that the spaghetti *is* cooked. Experimental pictures were available in two versions for each item (so fifty-six experimental pictures were used in total), with each version depicting the object in its different physical states (e.g. spaghetti, either cooked or raw), as described by the corresponding experimental sentence. Thus, one version shows the implied shape of the negative sentence (match), and the other the mismatch shape. Half the experimental sentences were paired with a picture that matched the described physical state of the object and half were paired with a picture that mismatched the described physical state of the object. Table 1 provides an example of such experimental sentences and the associated visual displays.

In addition, fifty-six filler items were used. These filler items included fourteen negative sentences and forty-two affirmative sentences. As with the experimental sentences, half were clefted (e.g. "It was Alice who broke the vase"), while the other half were non-cleft (e.g. "David washed his car"). All negative fillers were followed by an unrelated picture target (requiring a 'no' response). For affirmative sentences, twenty-eight were followed by a picture depicting the mentioned object (requiring a 'yes' response), and the remaining fourteen by an unrelated picture (requiring a 'no' response).

	Match	Mismatch
Clefted: *It was Jane who didn't cook the spaghetti* Non-cleft: *Jane didn't cook the spaghetti*		

Table 1 Example experimental sentence and the associated visual displays, as labelled.

One version of each sentence-picture pair was assigned to one of four presentation lists, with each list containing twenty-eight experimental items. Each list contained one of the four possible versions of each item (2 (clefted/ non-cleft) x 2 (match/ mismatch)), blocked to ensure that they were evenly distributed among the fifty-six fillers. Each participant only saw each item once, in one of these four lists. The participants' task was to decide whether the object in the picture had been mentioned in the preceding sentence. All experimental trials required a 'yes' response. Finally, comprehension questions followed twenty-eight trials (9 experimental) and were constructed such that participants needed to understand the whole sentence rather than simply focussing on the meaning of the noun.

Procedure

The experiment was conducted on an IBM 14" laptop using E-Prime software. Each trial began with the presentation of a single sentence and participants were instructed to press the space bar as soon as they finish reading this sentence. A centrally-located fixation cross then appeared for 250ms, followed by an image (approx 3 inch by 3 inch) in the centre of the screen. The participant responded to indicate whether the

object had been mentioned in the preceding sentence or not ("1" for yes and "0" for no). Comprehension questions (if applicable) appeared after the participant had responded to the image and again required yes/ no responses (with the same keys). All participants were told that response time and accuracy were measured, so they should make the decisions on images as quickly and correctly as possible and completed a short practice block at the start of the experiment. The entire experiment took approximately 15 minutes to complete.

3.3.2 Results

Analyses were performed on image response times. Prior to analysis all response times longer than 3000ms or shorter than 300ms were eliminated. After converting to Z scores, outliers were detected and eliminated using a Z score cut-off of 3.29 ($p < 0.001$). This eliminated 2.1% of the data. Mean reaction times are presented in Figure 1[15]. All participants scored at or above 80% accuracy on the comprehension questions.

We performed a 2 (cleft/ non-cleft) x 2 (match/ mismatch) x 4 (lists) ANOVA with Clefting and Match as the repeated measures factors and List as a between factor. Analyses were performed both by participant (F_1) and by item (F_2). The mean image response accuracy was 95.5%, SD=0.21, meaning that participants accurately responded to the sentence-picture pairs. Results from the ANOVA showed no main effects of Clefting [Fs < 0.55] or Match [Fs < 1.88]. Also List did not interact significantly with any other variables [All Fs < 1.81].

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15 All error bars figures in this thesis represent standard errors.

However, the results did reveal a significant interaction between Clefting and Match: $F_1(1,36) = 6.04$, $p < 0.02$; $F_2(1,27) = 7.54$, $p = 0.01$. Analysis of the simple main effects revealed that following non-cleft sentences, responses were significantly faster when the image mismatched ($\bar{x} = 992$) the implied visual image in the negative sentence than when it matched ($\bar{x} = 1054$): $F_1(1,39) = 4.02$, $p < 0.05$; $F_2(1,27) = 5.05$, $p < 0.03$. This result replicates Kaup and Zwaan (2007)'s findings. However, following cleft sentences, the pattern was reversed. Responses showed a trend (significant by participants) where responses were slower when the image mismatched ($\bar{x} = 1074$) the implied shape in the negative sentence than when it matched ($\bar{x} = 1007$): $F_1(1,39) = 4.33$, $p < 0.04$; $F_2(1,27) = 0.1$, $p = 0.76$.
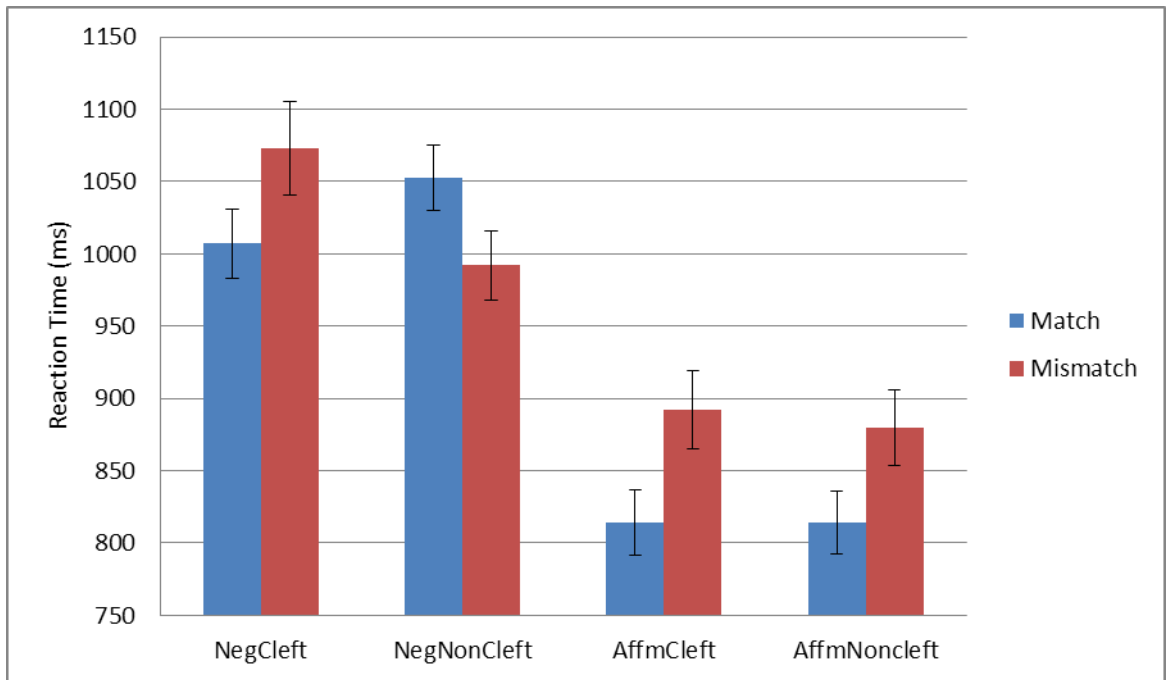
Figure 1 Reaction times for the four experimental conditions (Note: data for a follow-up study testing affirmative versions of these items are presented alongside). Error bars represent standard errors.

Taken together, the results suggest that 250ms after a cleft negative sentence, a mental image implied by the negated sentence is more active than the image implied by the alternative affirmative sentence. There is a reverse pattern for non-cleft sentence. This means that when processing a cleft negative sentence, participants didn't first mentally picture the shape which is to be negated (rejected). This result is not predicted by the two-step model for negation processing. Based on this theory, there should be no interaction between cleft/non-cleft and match/mismatch.

In the cleft condition, the faster response to the matching images suggests that participants accommodated the negative QUD, as predicted by the dynamic pragmatic account. However, it has been suggested to us that, due to the fact that

cleft sentences do not focus on the negative predicate, participants might not really process the negation in this condition. In that case, the faster response to the match images may have arisen due to properties of the images, for example the match images may have simply been easier to recognise.

In order to control for the potential effects of image, we ran a follow-up control study testing a new set of forty participants, but this time we replaced the negative sentences with affirmative ones (e.g. "Jane cooked the spaghetti" and "It was Jane who cooked the spaghetti"). Fillers were also adjusted accordingly to balance the negative and positive sentences of the two types. Mean reaction times are presented in Figure 1. Outliers were detected and removed as described in the main experiment. The results showed a main effect of Match, where participants were significantly faster to respond to images when they matched the sentence's affirmative meaning (e.g. "[Jane/ It was Jane who] cooked the spaghetti", followed by an image of cooked spaghetti) compared to when they mismatched [$F_1(1,36) = 14.51$, $p < 0.01$, $_p\eta^2 = 0.29$; $F_2(1,27) = 6.08$, $p = 0.02$, $_p\eta^2 = 0.18$]. Importantly, there was no main effect of Clefting [All Fs < 0.69] or a significant Match*Clefting interaction [All Fs < 0.07] in this affirmative version of the experiment. Thus we can conclude that there is no inherent difficulty in recognising either type of image and that in the main experiment, participants were processing negation in the cleft condition.

3.3.3 Discussion

Experiment 1 tested whether representing the positive counterpart is the mandatory first step of negation processing, as predicted by the two-step simulation account, or it is due to representing the prominent QUD, as predicted by the dynamic pragmatic account. We presented participants with simple or cleft negative sentences, followed by pictures that matched or mismatched the state of affairs indicated by the sentence. Results suggest that participants only represent the positive counterpart in the simple negative condition, but not in the cleft negative condition. This result supports the dynamic pragmatic account: negation and cleft construction are cues for the prominent QUD. When participants read sentences without supporting context, they use these cues to infer and accommodate relevant QUDs, which are represented in part as mental simulations of the state of affairs at issue. Participants will only represent the positive counterpart of a negative sentence if the QUD is positive. When the QUD is negative, as in the cleft condition, participants no longer represent the positive counterpart.

An implication of this explanation is that if the negative QUD associated with cleft negative sentences are shown directly, e.g. "who didn't iron their shirt?", participants will not first represent the positive counterpart (ironed shirt). Experiment 2 tests this prediction.

3.4   Experiment 2

This experiment tests the proposed explanation for experiment 1, specifically that in the cleft negative condition, participants did not respond faster to pictures consistent with the positive counterpart because a negative QUD was accommodated. The design of experiment 2 is identical to experiment 1, except that cleft negative sentences (e.g. It is John who didn't iron his shirt) are replaced by negative questions (e.g. who didn't iron their shirt?). This "question" condition is compared with simple negative condition (e.g. John didn't iron his shirt).

3.4.1   Method

Participants:

Forty-five English native speakers were recruited from Middlesex University in London. They are undergraduate students participating for course credits.

Design, materials and procedure:

The design and materials of experiment 2 is identical to experiment 1, apart from replacing cleft negative sentences with their QUDs. The same pictures and filler items were used.

Results

Data from five participants were discarded due to low accuracy. For data from the remaining forty participants, outliers were identified and eliminated in the same way

as experiment 1. Response times longer than 3000ms or shorter than 300ms were eliminated. After results had been converted to z scores, outliers were detected and eliminated using a z score cut-off of 3.29 ($p<0.001$). Incorrect responses were eliminated for RT analysis. In total 5.98% of data were eliminated. All participants scored at or above 75% accuracy on comprehension questions.

Reaction Time in ms	Simple	Question
Match	982	932
Mismatch	919	999

Table 2 Average RT per condition: experiment 2
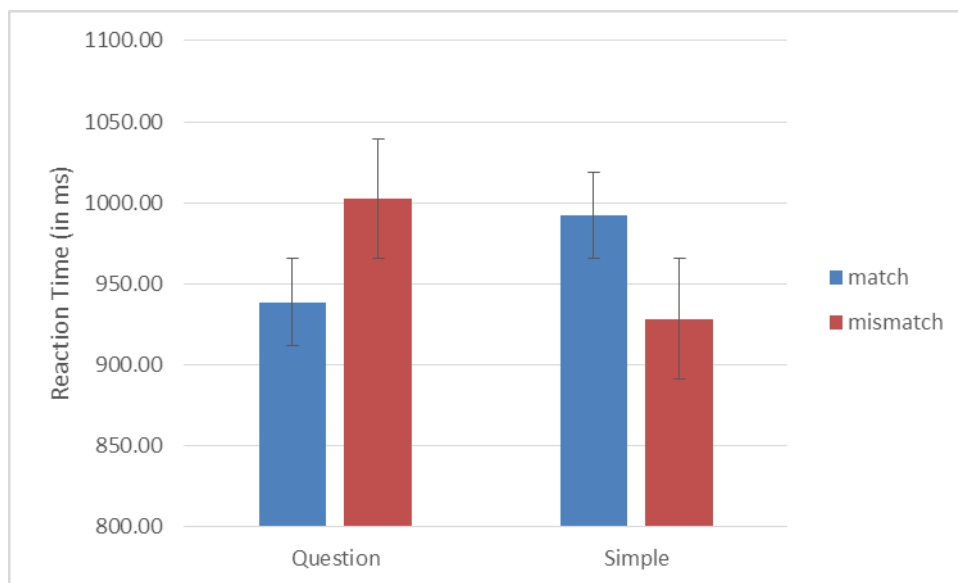
Figure 2 Average RT per condition: experiment 2

2(Question/simple) x 2(match/mismatch) x4(lists) analysis of variance (ANOVA) was performed. Analyses were performed both by participant (F_1) and by item (F_2).

The mean image response accuracy was 97.3%, mean comprehension question accuracy was 83.4%. There was no main effects of Question/simple ($F_s>0.31$), or match /mismatch ($F_s>0.42$).

The interaction between Question/Simple was significant by item $F_2(1,27) >6.30$, $p<0.02$. Analysis by participant revealed that the interaction is not significant at 95% but showed a strong trend. $F_1(1,39)>3.86$, $p<0.06$. Analysis of the simple main effects revealed that following simple negative sentences, responses to mismatched images were faster by trend: $t_1(39)=1.54$, $p=0.06$. $t_2(27)=1.31$, $p=0.10$. However, following negative questions, the patterned reversed numerically. Responses to MATCHED images were faster. The effect was not significant but trending: $t_1(39)=-1.55$, $p=0.06$; $t_2(27)=-1.04$, $p=0.15$.

3.4.2   Discussion:

Experiment 2 sets out to test the explanation proposed for the RT pattern for cleft items in experiment 1, which shows that shortly after reading a cleft negative sentence, participants respond faster to pictures that *match* the negative sentence meaning, contrary to the results of simple negative sentences. I proposed that the polarity of the accommodated QUD is what accounts for this effect. Cleft negative sentences project a negative QUD, which is why in this case participants did not represent the positive counterpart. Experiment 2 presented negative questions directly as stimuli in the same probe recognition paradigm, and found responses to

negative questions were like responses to negative clefts. This result supports the

proposed explanation of the dynamic pragmatic account[16].

If the accommodation of positive QUDs during negative sentence processing gives

rise to a mental simulations of state of affairs implied by both the positive

counterpart and the negative sentence, will we see the same effects in processing

positive sentences with prominent negative QUDs? Experiment 3 investigates this

question.

3.5 Experiment 3

Results from experiment 1 and 2 show that the positive counterpart is not always

represented when processing negative sentences. My explanation is that it is the

polarity accommodated QUD that determines whether the positive counterpart is

represented. In the cleft condition, the negative sentences project a prominent

negative QUD, e.g. "who didn't iron his shirt", which is why the positive counterpart

was not first represented.

If QUD accommodation affects the representations formed during sentence

processing, what happens with a *positive* sentence that projects a prominent *negative*

QUD? In Chapter 2 I suggested that a positive sentence with an accented auxiliary

projects a prominent negative QUD. For example, "I DID call my mum" answers the

QUD "did you not call your mum?". If participants read positive sentences that have

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[16] It is also possible that the effect were due to the representation of the negative
presuppositions (e.g. "someone didn't iron their shirt") associated with the negative questions
(e.g. "who didn't iron their shirt?").

prominent negative QUD, will they represent a state of affairs that is consistent with the negative counterpart?

To test this, we need a structure or a particle that is used in positive sentences that answer a negative QUD. In order to test this hypothesis using the picture probe recognition paradigm. I turned to the Dutch particle "wel", which is a particle used only in positive sentences. Hogeweg (2009) studied the use of "wel" in corpus, and found that positive sentences with "wel" are used to deny explicit negative statements, implicit negative expectations, or to show contrast, illustrated in the examples below (Hogeweg, 2009: 520):

23) *Jij heet   echt geen   Jan-Peter!*

   you name + have really no   Jan-Peter.

   'Your name isn't Jan-Peter!'

   Ik heet   wel   Jan-Peter!

   I name + have WEL Jan-Peter.

   'My name is Jan-Peter!'

24) *Jij   zag me niet, maar Peter wel.*

   You saw me not,   but   Peter WEL

   "You didn't see me, but Peter did."

All different uses of "wel" share the property that "they are a denial of a denial in the context. (ibid: 538). The original denial might be explicitly stated or inferred from the linguistic or non-linguistic context. When used alone, "wel" a response to a negative question or claim. This is clear when we look at Dutch answer particles to

polar questions. In Dutch, positive polar questions are answered with "ya" (yes) or "nee" (no). Negative polar questions on the other hand, require different answer particles for "yes". If the answer is a denial, the particle is "yawel", which is "yes" plus "wel".

25) *Ging Jan naar het feest?*   *-Ja / Nee*

    Did John go to the party? - Yes /No

26) *Ging Jan niet naar het feest?* *-Jawel / Nee*

    Did John not go to the party? - Yes (John did go to the party) /No (he didn't go)

This shows that "wel" is used in positive sentences only when the QUD is negative. Experiment 3 uses the same methods as experiment 1 and 2, and manipulates whether positive sentences contain "wel". If QUDs give rise to simulations, we should expect that after reading positive sentences with "wel", participants respond faster to situations consistent with the *negative* state of affairs, namely a picture that mismatches the situation described by the positive sentence. Positive "wel" sentences should give rise to a mirrored RT pattern of simple negative sentences:

27) *Experiment* 1:

    Sentence: John didn't iron his shirt. (negative)

    QUD: Did John iron his shirt? (positive)

28) *Experiment* 3:

    Sentence: John "wel" ironed his shirt. (positive)

    QUD: Did John not iron his shirt? (negative)

3.5.1 Method

Participants

Forty six native Dutch speakers participated in the experiment. Twenty-five were recruited from Belgium, and twenty-one were recruited from Radboud University Nijmegen. They were undergraduate students participating for course credits.

Materials and Procedure

Like experiment 1 and 2, we used a picture probe recognition task. All experimental sentences were positive, and the main manipulation was whether the sentence contained the particle "wel" or not. For example,

29) *Bob heeft de banaan gepeld. / Bob heeft de banaan wel gepeld.*

   Bob has peeled the banana. / Bob really has peeled the banana.

30) *Wout heeft spaghetti gekookt. / Wout heeft wel spaghetti gekookt.*

   Wout has cooked the spaghetti. / Wout really has cooked the spaghetti.

The verb phrase of all experimental sentences describes the physical state of an object. 28 experimental items were constructed, generating 28*2 = 56 experimental sentences (every item appears in both the plain form and the "wel" form). Like experiment 1 and 2, each sentence is paired with a picture depicting the noun (e.g. banana, spaghetti) that matches or mismatches the physical state of the object. Every participant sees 28 experimental sentences, half of which are paired with a picture

that matched the described physical state of the object. In addition, 28 filler items were used. In order to conceal the purpose of the study, various types of sentences are used. There are eight positive sentences with "wel" and eight simple positive sentences, all of which are paired with pictures of items that are not mentioned in the sentence. There are twelve negative sentences (e.g. Piet heeft zijn soep niet opgegeten. English translation: Piet didn't finish his soup), eight of which are paired with pictures of items not mentioned. Altogether, every participants sees 56 sentence-picture pairs, 32 of which require a "yes" response, and the remaining 26 require a "no" response". Finally, comprehension questions followed twenty-two trials (eleven after experimental item). They were constructed such that participants needed to understand the whole sentence rather than simply focussing on the meaning of the noun.

The procedure is the same as experiment 1 and 2. All instructions were given in Dutch. The whole experiment takes around 15 minutes.

Results and Discussion

Data analysis follow the same procedure as experiment 1 and 2. Six participants were excluded because their overall accuracy is lower than 80%. Two items were removed due to errors in Dutch sentences. Prior to analysis all response times longer than 3000ms or shorter than 300ms were eliminated. After converting to Z scores, outliers were detected and eliminated using a Z score cut-off of 3.29 (p < 0.001). This eliminated 2.8% of the data. The overall accuracy for comprehension questions is

78%, all participants scored over 70% in comprehension questions. The mean image response accuracy was 94.7%.

In terms of accuracy, 2 (wel/simple) x 2 (match/ mismatch) ANOVA shows that there is no significant interaction in accuracy (Fs < 1.72, Ps >0.2). Instead, match/mismatch has a significant main effect: $F_1(1,39)= 10.225$, $p_1 = 0.003$. $F_2(1, 25)= 9.62$, $p_2 = 0.005$. Wel/simple has no main effect.

Average accuracy	Match	Mismatch
Simple	0.96	0.92
Wel	0.98	0.91

Table 3 Mean accuracy per condition, experiment 3

Mean reaction times per condition are shown in Table 4. The difference between match and mismatch in the simple condition is numerically bigger than that the "Wel" condition, which matches our prediction. However, a 2 (wel/simple) x 2 (match/ mismatch) ANOVA revealed no significant match by wel interaction: $F_1(1,39)= 0.39$, $p_1 = 0.54$; $F_2(1, 25)= 0.11$, $p_2 = 0.74$. There are no significant main effects of "wel": $F_1(1,29)= 1.91$, $p_1=0.1$; $F_2 (1,25) =2.72$, $p_2=0.11$, and no main effect of "match": $F_1(1,39) = 1.91$, $p_1=0.175$; $F_2 (1,25) =1.84$, $p_2=0.19$. These tests figures are surprising given the results of experiment 1 and 2. Paired-sample t-tests also failed to show a significant difference between simple match and mismatch: $t_1(39)= -1.43$, p_1 (two-tailed) $=0.16$; $t_2(25)= -1.05$, $p_2=0.30$, and between "wel" match and mismatch: $t_1(39)= 0.60$, p_1(two-tailed) $= 0.55$; $t_2(25) = -0.70$, $p_2=0.49$.

The overall average RT for simple condition is 759.98ms, and for "wel" condition is 789.17ms. Paired-sampled t-test shows that the difference is not significant but trending. If we hypothesize that simple condition should be faster than "wel" condition, and thus conduct a one-tailed t-test, the difference is significant by item: $t_1(39) = -1.48$, p_1(one-tailed) = 0.07; $t_2(25) = -1.89$, p_2(one-tailed) = 0.035.

The overall average RT for "match" is 760.98ms, and for "mismatch" 789.08ms. Paired-sampled t-tests show that the difference is not significant even if we hypothesize a one-tailed distribution: $t_1(39) = -1.24$, p_1(one-tailed) = 0.11; $t_2(25) = -1.27$, p_2(one-tailed) = 0.11.

RT in ms	Match	Mismatch	Total
Simple	738.42	782.53	759.98
Wel	783.11	795.77	789.17
Total	760.98	789.08	

Table 4 Mean RT per condition, experiment 3
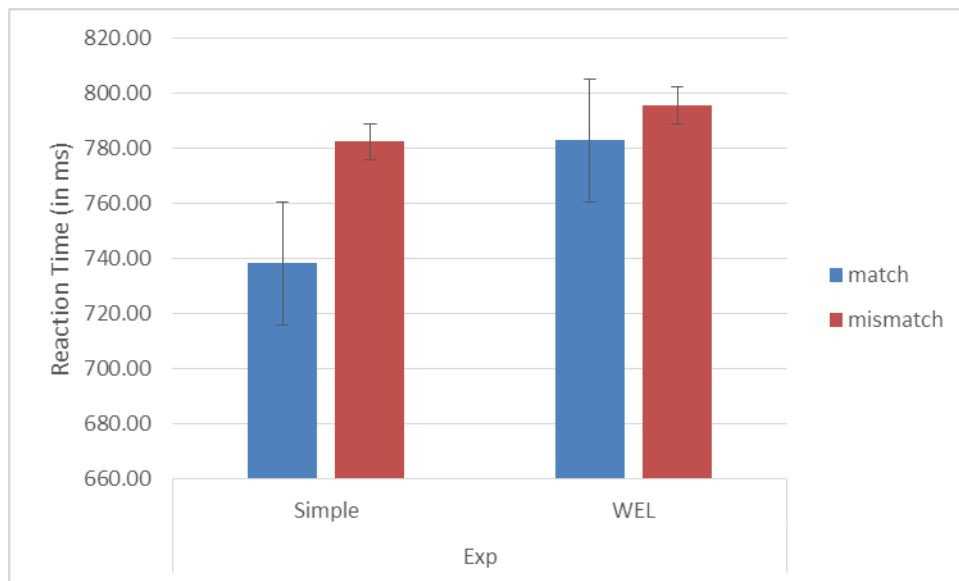
Figure 3 RT per condition: experiment 3

3.5.2   Discussion

Experiment 3 was conducted to test whether processing positive sentences with a negative QUD involve a simulation of the negative state of affairs shortly after reading the sentence. However the results did not yield any statistically significant results, and thus is non-indicative for the current hypothesis. What is surprising is that we failed to replicate the findings of Zwaan, Stanfield, & Yaxley, 2002, the positive condition in Kaup, Yaxley, Madden, Zwaan, & Lüdtke, 2007, as well as the positive control study in experiment 1, even though the direction and the scale of the numerical difference is similar to the positive control study in experiment 1. The lack of statistically significant differences is likely due to the high variability among participants. It is possible that some of the participants did not process the sentence fully, but focused only on the noun (the average response time in experiment 3 is faster than that of the positive control study in experiment 1).

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Given that we failed to obtain a statistically significant difference between simple match and mismatch conditions, little can be confidently inferred from the results of "wel" match and mismatch results. With this in mind, I will discuss the numerical results with caution, aiming only to guide future studies. We predicted that the response time pattern of "wel" condition should resemble the mirror image of the simple negative condition in experiment 1. This prediction was not borne out. However, the numerical pattern shows that the difference between "wel" match and mismatch is smaller than that of simple match and mismatch. This suggests that the QUDs for "wel" sentences may have influenced the mental simulations. We didn't see a mirror image pattern of simple negatives. This could be because some participants in this experiment didn't process the sentences fully. In addition, it could be that simulating the state of affairs consistent with the negative QUD requires more time, and thus the effect is not shown at 250ms ISI. While a positive QUD (e.g. whether John ironed his shirt) directly described the state of affairs at issue (ironed shirt), a negative QUD (e.g. whether John didn't iron his shirt) only indirectly implies the state of affairs at issue. Therefore, mentally simulating a negative QUD may take longer than simulating a positive QUD.

3.6   General Discussion

The purpose of the study was to find out whether a simulation of the positive counterpart of negation is necessary to represent negation in comprehension or whether such simulations are triggered as a by-product of the pragmatics of discourse interpretation. The results indicate that the effect of negation on response latencies of matched or mismatched images is not due to a mandatory two-step processing

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mechanism for negation. As predicted by the dynamic pragmatic account, we only find evidence of positive simulations after reading a simple negative sentence. In contrary, after cleft negative sentences or negative questions, we find the opposite pattern. One might have thought that a cleft sentence with a negative clause should take longer to process than a simple negative sentence, due to the need to accommodate the presupposition triggered by the clefting. However, participants here were faster at recognizing pictures that matched the described situation after reading cleft sentences. This is explained on the dynamic pragmatic account where simple negative items trigger their own accommodation process.

While our results pose problems for the two-step simulation model for negation found in Kaup et al (2006, 2007), these results do not contradict the broader simulationist programme (Barsalou, 1999; Zwaan, 2004) insofar that programme explores the nature of semantic representations for language comprehension. There is a rich tradition in semantics beginning with David Hume and found in contemporary situation-theoretic research (Barwise & Perry, 1983). In that tradition, situation semantics has long grappled with the meaning of operators such as negation (Barwise, 1989; Cooper, 1998). One important insight that distinguishes situation semantics from traditional possible worlds semantics is that the assertion of a negative sentence should strongly imply that there is a situation which supports this (Cooper, 1998). The findings in the present chapter supports this implication (i.e. for "the bird isn't in the air", people represent a scene that provides support for the claim – like a nesting bird). However, there is nothing in the meaning of negation from a situation theoretic point of view that would mandate a two-step process for

representing an interpretation of an utterance containing negation. While it is an

empirical question whether people in fact process negation in two-steps, the results

of the study presented here suggest that they need not.

Chapter 4 Negation and sentence verification

4.1 Introduction

There is a long tradition of research into how negative (as compared to positive) sentences are verified. This research is widely regarded as being significant for the nature of representational states involved in language processing. The rising interest in sentence verification in the 1960s was sparked partly by the rising popularity of information-processing research which studies how humans and machines process information, form concepts, construct and test hypotheses (cf. Hunt, Marin, & Stone, 1966; Levine, 1966). Human information processing is closely linked to and partially depends on language comprehension. The general assumption among psycholinguists was that sentence verification is integral to language comprehension. Studying verification would be highly informative for language comprehension. This interest has in turn generated interest in the research in negative sentence comprehension, due to the inseparable relation between negation and truth value.

Studies in sentence verification usually participants to verify sentences either against given evidence (often a picture) or against world knowledge. In sentence-picture verification studies, participants are asked to judge the truth value of an affirmative or a negative sentence against a picture. These studies were either interested in the nature of sentence verification itself, or they used this paradigm to study the processing of linguistic features, especially negation. For example, in Clark and Chase (1972), participants were shown a sentence such as (13) to (16) alongside a

picture that makes the sentence true or false. Sentence polarity (affirmative[17] or negative) and truth value (true or false) categorize the items into four types (TA, FA, TN, FN). Reaction times and error rates are measured and compared among these four types.

31) The plus is above the star. (True Affirmative, TA here after)

32) The star is above the plus. (False Affirmative, FA here after)

33) The star isn't above the plus. (True Negative, TN here after)

34) The plus isn't above the star.(False Negative, FN here after)

Picture:
$$+$$
$$\star$$

Across different studies, results consistently show a main effect of polarity: verifying negative sentences causes more errors and takes longer than verifying affirmative sentences. This has been seen as evidence that negative sentences are harder to process than affirmatives. When verifying an affirmative sentence, true ones are easier than false ones (TA<FA). This is where the consistency in results ends. With negative sentences, results point in different directions. Many studies found that true negatives are in fact harder than false negatives, thus reporting a polarity by truth value interaction (TA<FA<FN<TN). Some studies found that true and false negatives are equally difficult: TA<FA<FN=TN. Yet others found that true negatives are easier than false ones, thus reporting a main effect of polarity and a main effect of truth value: TA<FA<TN<FN. Table 5 surveys the paradigms used in some

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[17] In this chapter, "affirmative" and "positive" are used interchangeably.

verification studies based on reaction time (RT) differences between TN and FN. In Table 5, "type of predicate" refers to whether the predicate is binary (e.g. dead/alive, where the negation of one entails a unique contrastive alternate), binary only in the experiment (when only two properties can appear in the experiment, for example a shape can be either white or black; in such a context, "not white" means "black", even though normally being white is not a binary predicate), or unary (when the negation of the predicate is compatible with two or more possibilities, such as "being red" when at least three colours may appear).

The survey in Table 5 is in no way comprehensive, yet it is clear that the differences in reaction times between TN and FN are not consistent across studies: verifying TN may take less, equal amount or more time than FN. This inconsistency suggests that negation may bring certain complications to sentence verification: while RT associated with negative sentences seem to be affected by various factors, the same factors don't affect the RT pattern for affirmative sentences, as TA<FA is found across all paradigms.

Despite the fact that different patterns between TN and FN have been reported, current models on sentence verification generally explain only one pattern. The polarity by truth value interaction pattern is the most reported and perhaps interesting pattern, and thus has received the most amount of attention.

Grammatical transformation theory (Gough, 1965, 1966) focuses on the extra difficulty of negative sentences compared to affirmative sentences, and suggests that this is because negative sentences require grammatical transformation from their

positive "kernels". This account, however, remains silent on why sometimes polarity interacts with truth value. Due to its limited explanatory power, I will not discuss this account.

The conversion model (Trabasso & Rollins, 1971) explains the main effect only result (TN<FN). They propose that negative sentences are converted into a positive sentences by default whenever possible. Therefore, verifying true sentences should take less time than verifying false ones, regardless of their surface polarity.

Rejection accounts (Carpenter & Just, 1975; Clark & Chase, 1972; Kaup, Zwaan, & Lüdtke, 2005) are by far the most dominant accounts in sentence-picture verification, and they focus on the interactive pattern TA<FA<FN<TN. Although different accounts differ in the nature of representation (propositional or experiential/ image-like), they share the idea that negative sentences are represented as a positive argument or core embedded in a negation operator. For example, "the star isn't above the plus" is represented as "not (the star is above the plus)". In a verification task, the truth value of a negative sentence is the opposite of its positive core, i.e. the core of TN is FA, and the core of FN is TA. This is why the RT for a negative sentence patterns with an affirmative sentence with the opposite truth value, resulting in a polarity by truth value interaction.

Mayo, Schul, and Burnstein (2004) propose that both the conversion model and rejection accounts are used to represent negative sentences: those with a unipolar predicate are represented by a positive core embedded in a negation operator, while

those with a binary predicate are transformed into a positive sentence. This account predicts TN > FN with unipolar items and TN < FN with binary items.

In this chapter, I first review current models in more detail, and discuss their merits and disadvantages. I then present an explanation for the empirical findings using the dynamic pragmatic perspective. Lastly, I present five experiments testing these accounts.

Type of study	Reaction time: TN vs. FN	Reference	Example of negative sentence	Type of predicate	Evidence	Presentation	Total no. of trials (prac+ exp)
Sentence-picture	TN > FN	Carpenter & Just, 1975	It is true that the dots aren't red.	unary	coloured dots	sentence first	288
		Just & Carpenter, 1976	The plus isn't north.	unary	four symbols in four locations (north, south, east, west): a plus in one location and a star each in the other three	simultaneous	111
		Lüdtke, Friedrich, De Filippis, & Kaup, 2008	In front of the tower there is no ghost.	binary in context	Picture of a tower with a lion or a ghost in front	sentence first	344
		Clark & Chase, 1972	The plus isn't above the plus.	binary in context	a plus and a star vertically arranged	simultaneous	176
		Trabasso & Rollins, 1971	Not green	binary in context	coloured shapes	picture first	192
	TN = FN	Gough, 1965, 1966	The boy did not hit the girl.	unary	picture of a boy and a girl, one hitting or kicking the other	sentence first	144
		Trabasso & Rollins, 1971	Not green	binary in context	coloured shapes	picture first	192
	TN < FN	Trabasso & Rollins, 1971	Not green	binary in context	coloured shapes	sentence first	192
		Young & Chase, 1971	The plus isn't above	binary in context	a plus and a star vertically arranged	simultaneous	unknown

Type of study	Reaction time: TN vs. FN	Reference	Example of negative sentence	Type of predicate	Evidence	Presentation	Total no. of trials (prac+ exp)
sentence-sentence	TN < FN	Mayo, Schul, & Burnstein, 2004	Tom's clothes are folded neatly in this basket.	binary	Tom is not a tidy person.	Evidence first	43
	TN = FN	Mayo et al., 2004	(unknown)	unary	Tom is not a creative person.	Evidence first	43
sentence-world knowledge	TN < FN	Arroyo, 1982	Paris is not an American city.	unary	N/A	A context set is given beforehand, e.g. "Miami, Paris, Dallas, Chicago", where the odd-one-out item is the subject of the following sentence	64
	TN > FN	Arroyo, 1982	Paris is not an American city.	unary	N/A	No context set given	64
	TN = FN	Wason, 1961	Sixty-four isn't an odd number.	binary	N/A	Sentence only	24
	TA > FN	Fischler, Bloom, Childers, Roucos, & Perry, 1983	A robin is not a tree/ bird.	unary	N/A	Sentence word by word	288

Table 5 Survey of sentence verification studies

4.2   Current models of sentence verification

4.2.1   Conversion code matching model

Trabasso and Rollins (1971) conducted a series of experiments to investigate the process of verifying hypotheses against evidence. In one of these experiments, participants were shown a description (in the form of a phrase rather than a sentence), and an image of a geometric figure whose property either matched or mismatched the description. Participants answered whether the description was true or false according to the image by pressing a button. Only two colours could appear in the pictures, and thus the descriptions are binary in this experiment. For example, the colour of the geometric figure could either be orange or green, and the description could be "(not) orange" or "(not) green".

When the participants read the descriptions before seeing the figures, RT showed main effects of polarity and truth value: affirmative descriptions were judged faster than negative ones; true descriptions were judged faster than false ones: TA<FA<TN<FN. However, when the description was shown after the image, there was an interaction between polarity and truth value: for affirmative descriptions, true ones were judged faster than false ones. For negative descriptions, false ones were faster than true ones: TA<FA<FN<TN.

Trabasso and Rollins explained these results with the code-matching model. They suggest that participants code the two inputs (description and picture) in sequence in the positive form whenever possible. If a sentence is negative, negation is removed by incorporating it with the predicate to infer a positive state of affairs. For example, "not orange" would be converted to "green" if the participants learned that being

orange and green are the only two possible attributes. After the coding stage, the participant matches the codes from the two inputs and set the response. The default response is "TRUE" or "SAME". Whenever a mismatch is detected, the response is flipped (for example from "TRUE" to "FALSE"). Each flip adds a certain amount of time to RT. When descriptions are presented first, TA has no mismatches and FA has one, thus FA is slower than TA. Negative descriptions are transformed which adds to response time. After the transformation, there is 0 and 1 mismatch respectively for TN and FN, thus FN is slower than TN. When descriptions are presented after the image, negative descriptions are no longer transformed. In this case, there are 2 and 1 mismatches respectively for TN and FN, so FN is faster than TN. While the conversion model explains the results of Trabasso and Rollins (1971), it is incompatible with several studies in Table 5 where a polarity by truth value interactive RT pattern was reported with sentence first presentations.

4.2.2   Rejection models

While the conversion model assumes that negation is removed from the sentence representation by default via conversion, rejection models propose that negation is represented as an operator. Different rejection models disagree in terms of the nature of representation.

4.2.2.1   Constituent comparison model

Constituent comparison models, notably proposed by Clark and Chase (1972) and Carpenter and Just (1975), assume that the content of both the sentence and picture are represented in a propositional format. Negative sentences are represented by a positive constituent embedded under a negation marker, rather than being converted

to positive sentences by default. It is best illustrated by studies by Clark and Chase (1972) and Carpenter and Just (1975).

Clark and Chase (1972) conducted an experiment in which participants were shown an image containing two objects such as a star and a plus (one above the other) alongside a sentence which described their spatial relation. Participants decided whether the sentence was true or false according to the image. The sentence and the image were shown on the same screen. Participants were asked to either read the sentence first, or look at the picture first. In both cases, response times show a polarity by truth value interaction: TA<FA<FN<TN. Carpenter and Just (1975) found a similar effect. Participants read sentences which describe the colour of some dots (e.g. "It is true that the dots are red"), and then saw an image of some dots in red, green, or black. Notice that in this setup, the value of the predicate is not binary. Their results also showed a TA<FA<FN<TN pattern in response time.

Clark and Chase propose that both sentence and picture are coded in a propositional format. Specifically, sentences are coded in a form that is consistent with their linguistic "deep structure". They assume that sentential negation takes the scope of the entire embedding proposition. A sentence like "plus is not above star" would be coded as "false (plus above star)". Coding a sentence with "below" would take longer than "above" due to the frequency difference between "above" and "below"; coding a negative sentence would take longer than a positive one due to an embedding process. Pictures are always coded in an affirmative format such as "above [star, plus]". If participants read the sentence before the picture, they will tend to use the same relative position predicate (e.g. above) that appeared in the sentence to code the picture. If pictures are processed first, "above" is used by

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default in the picture representation. After both inputs are coded, the two representations are compared constituent by constituent from the "inside out", starting from the innermost constituent. The original truth index is set as "true". Every time a mismatch is detected, the response index switches. Comparison time reflects the total number of switches. According to this model, TA triggers no mismatch, FA and FN each triggers 1 mismatch, while TN triggers 2 mismatches (see Table 6 for a summary of sentence and picture representations). Note that both FA and FN involve 1 mismatch, and yet FN has been shown to take longer than FA. To explain this difference, Clark and Chase named the time it takes to detect a mismatch in the embedding string the "falsification time", while the extra time caused by negation (including extra time in coding and detecting a mismatch in the polarity operator) "negation time". They assume that a mismatch in the polarity marker can add more time than a mismatch in the embedding positive core.

Type	Sentence	Representation	Picture	Mismatches
TA	The plus is above the star.	(plus above star)$_{sen}$	(plus above star)$_{Pic}$	0
FA	The star is above the plus.	(star above plus)$_{sen}$		1
FN	The plus isn't above the star.	False (plus above star)$_{sen}$		1
TN	The star isn't above the plus.	False (star above plus)$_{sen}$		2

Table 6 Sentence and picture representations (Clark & Chase, 1972)

This model is inconsistent with the finding that sometimes a main effect of polarity only pattern is observed (TA<FA<TN<FN). To account for this, Clark and Chase propose that participants have two strategies to choose from: they can either follow the process mentioned above: code the content of the sentence with a negation operator over a positive argument and use the truth function of negation to switch the truth index (the truth functional strategy), or they make an inference about the states of affairs that makes the negative sentence true, thus "converting" the negative sentence into a positive one (the conversion strategy, following Trabasso & Rollins, 1971). The participants' choice of strategy is influenced by the manner of stimulus presentation (picture first or sentence first), type of predicates (binary or unary), instructions and participants' preference. If pictures are presented first, participants are more likely to choose the truth functional strategy than the conversion strategy. If the predicates are unary (when the negation of a predicate is less specific than itself, e.g. the dots are not red), participants are more likely to choose the truth function strategy. Participants can also be explicitly instructed to convert the negative sentences into positives during a verification task (Young & Chase, 1971). In addition, Clark (1974) suggests that subjects can "spontaneously" adopt one or the other strategy. A similar claim has been made by Carpenter & Just (1975). However, they do not specify when participants would invoke a particular strategy or why.

Carpenter & Just (1975) subsequently proposed a similar model which also assumes that negative sentences are represented by a positive argument embedded under a negation marker. The representations of sentences and pictures are compared inside out, where a mismatch flips the response index. It differs from Clark and Chase's model in the assumptions that (1) a mismatch reinitiates the entire comparison

process, with the mismatched constituents being tagged and treated as a match in subsequent comparisons; (2) a comparison between the two constituents consumes a fixed amount of time. The total comparison time is determined by the value of a parameter k, which is an index of the number of comparisons involved to verify TA. Unlike Clark and Chase's model, the time consumed in switching the truth index is practically negligible in Carpenter and Just's model. Because a mismatch causes the entire comparison process to start again from the inner most position, a mismatch further away from the core incurs more cost. They propose that if a TA requires k comparisons, then FA requires $k+1$ comparisons as the mismatch is in the innermost constituent; FN requires $k+2$ comparisons, and TN requires $k+3$ comparisons. This assumption explains why FN takes longer than FA, i.e. why "negation time" is longer than "falsification time": a mismatch in the polarity marker is further away from the core than a mismatch in the positive argument. Therefore, a difference in polarity marker causes more loops of comparisons than a difference in the positive core, and thus consumes more time. Carpenter and Chase differentiate sentential denials such as "it isn't true that the dots are red" from predicate negatives such as "It's true that the dots aren't red". The former is represented as {NEG [AFF] (RED, DOTS)} while the latter is represented as {NEG (RED, DOTS)}[18]. A picture of red dots is represented as {RED, DOTS}. As the mismatch in the polarity operator in sentential denials is further away from the core than predicate negatives, verifying sentential denials take longer than predicate negatives.

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[18] Tanenhaus, Carroll and Bever (1976) pointed out that there are discrepancies in the notations of representations. For example, it is unclear why "it is true that the dots are red" are represented as "{NEG (RED, DOTS)} rather than {AFF [NEG (RED, DOTS)]}. For both sentence and picture representations, affirmative operators are eliminated inconsistently and without good justification.

4.2.2.2   Two-step simulation account

The two-step simulation account (Kaup et al., 2005) is also based on the idea that a negative sentence is a rejection of a positive argument, but it disagrees with the assumption that sentence and picture are represented in propositional format. Rather, they propose that sentences are represented with experiential, image-like simulations (Kaup, Zwaan, et al., 2007). Negative sentences are processed with two stages: first a simulation of the positive argument, then this is discarded and replaced with a simulation consistent with sentence meaning (if possible). In sentence-picture verification tasks, the RT pattern is determined by whether the sentence representation is in the first or the second stage, when it is compared with the picture. If the picture is presented alongside or immediately after the sentence, the comparison happens when the participants are still focusing on the first stage of negation processing – the positive argument. In this stage, the representation of FN matches the picture, and TN mismatches the picture. They assume the responses are faster when two representations match then when they mismatch, predicting FN<TN and thus a polarity by truth value interaction. However, if the picture is presented with a longer delay after the sentence, participants will have shifted their attention to the second stage representation – the actual situation. At that time, the representation of FN mismatches the picture, and TN matches the picture, thus predicting FN>TN and no interaction between polarity and truth value.

To test their prediction, Kaup et al. (2005) conducted a probe-recognition experiment using similar materials as Clark and Chase (1972), such as the sentence "the pineapple is not above the rooster", and a picture of a pineapple and a rooster whose spatial relation match or mismatch the sentence. The picture appeared either at 0ms

or 1500ms after participants finished reading the sentence. The task however was not to verify the sentences, but to indicate whether both items in the picture have been mentioned in the sentence. They found that with 0ms delay, there was an interaction in RT (TA<FA, FN<TN). With 1500ms delay, reaction times to true and false negative sentences were the same (TA<FA, TN=FN). With this result, they suggested that the difference in reaction times in previous sentence-picture verification tasks studies "differences in the degree to which the picture is primed by the representations that are available from processing the sentence" (Kaup et al., 2005:5). Their reasoning is that when picture are presented soon after the sentence, participants are still in the first stage of processing the negative sentences (representing the positive argument). The first stage representation is compared with the picture, where a match results in a faster response. The question is, how does this comparison allow truth value judgment? If participants have not finished processing the meaning of the negative sentence, it is unclear how they can identify its truth value against the picture.

4.2.3   Predicate dependent coding model

Mayo et al. (2004) pointed out that the models discussed above do not take into consideration the types of predicates in the negative sentences and the different levels of inferences that can be drawn. A negative sentence with a binary predicate (e.g. the shop is not open) allows us to infer specific state of affairs (the shop is closed) whereas a negative sentence with a unary predicate (e.g. the dress is not red) is consistent with many possible states of affairs. Mayo et al. suggest that both the conversion model and rejection model can be used to form representations of sentences. The choice between the two depends on the type of predicates. If the

predicate is binary, negation should be incorporated or "fused" with the predicate, in which case the negative sentence will be represented in a positive format. On the other hand, when the predicate is binary, no specific positive situation can be inferred. In this case, the negative sentence is represented with a "schema-plus-tag", i.e. a positive argument embedded under a negative operator.

Their experiment (Mayo et al., 2004) tested this idea using a sentence-sentence verification task. Participants first read a description of a character (e.g. Tom is not a tidy person), and then were asked to judge whether a description is congruent or incongruent (e.g. "Tom's clothes are folded neatly in his closet" / "Tom forgets where he left his car keys"). Their results showed a main effect of polarity and of truth value when the predicates are binary (TA<FA<TN<FN), but a polarity by truth value interaction when the predicates are unary, suggesting that the types of predicates determine the type of representation. In a post-hoc memory test, participants made more errors when reporting the meaning of negative sentences with unary predicates than those with binary predicates. A common mistake with unary predicated sentences was that participants forgot that there was a negation marker and remembered only the meaning of the positive core (e.g. remembering "not responsible" as "responsible").

Note that in the study of Mayo et al. (2004), the unary or binary status of a predicate does not depend on the experiment context. For unary predicates (e.g. adventurous), over 80% of the pre-test participants could not think of an opposite descriptor or had to use negation to construct an opposite, while for binary predicates (e.g. warm), over 80% of the participants gave a consistent opposite descriptor (cold). It is unclear

whether a predicate that is only binary in an experiment (e.g. "being red" when only red and black can appear) triggers conversion.

4.3 Discussion and criticism of current models

The immediate shortfall of all models is their limited explanatory power when confronted with the diverse findings in the RT patterns of TN and FN. The conversion model cannot account for findings of TN>FN when sentences are presented first. The two-step simulation model has no way to explain main effect only patterns when pictures are presented alongside or immediately after the sentences. Propositional representation models (Carpenter & Just, 1975; Clark & Chase, 1972) acknowledge the possibility of two available strategies, however they do not explain when and why a particular strategy is adopted. The predicate dependent model (Mayo et al., 2004) does make explicit predications on the choice of strategy based on the type of sentence predicate. However, it is unclear whether this distinction applies to predicates that is binary only in the experimental context. If it does, then the prediction is inconsistent with previous findings (e.g. Clark & Chase, 1972; Kaup et al., 2005).

In addition, current models rely on several assumptions. I will discuss four general assumptions and whether they are justified.

(1)   Does sentence-picture verification require a "common language"?

A basic assumption of all models of sentence-picture verification is that both inputs must be represented in a "common language" before they can be compared. This is an intuitive idea, but is it theoretically necessary that the verification of information of two modalities require a common language?

Tanenhaus, Carroll, & Bever (1976) argues that this need not be the case. Following Bever (1975), they argue that inputs of two faculties, say faculty A and B, can have functional equivalence as long as there is a mapping mechanism that maps inputs of A to the domain of B, and a mapping mechanism that maps the inputs of B to the domain of A, but the two mapping systems can be distinct. In this case, A and B can be functionally equivalent without there being representations in a "common language". They used the example of a typewriter to illustrate this point. A typewriter translates the kinetic motions of the fingers into letters. This mapping mechanism is unidirectional. Letters on a piece of paper cannot be mapped back into kinetic motions of the fingers using a typewriter. However we can imagine a system that detects the letters on a piece of paper, and maps the letters into kinetic motions of robotic fingers. With these two distinct mapping mechanisms, the kinetic motions of fingers and letters on paper are functionally equivalent.

In terms of sentence-picture verification, the idea is that if there is a mechanism (or a series of mechanisms) that maps a sentence onto an actual picture and a different mechanism that maps a picture onto a full sentence, the two inputs can be functionally equivalent without being represented using a "common language". However, simply mapping a sentence onto a picture does not result in *verification*. We do still need to compare the picture mapped from the sentence with the picture we are presented with to detect sameness or differences. Likewise, if a picture is mapped onto a fully fledge sentence, we still need to compare two sentences. In this sense, sentence-picture verification does require a "common language" for comparison, be it sentences, pictures or representations in a third format.

(2)   Can we assume that identifying a match is easier than a mismatch?

A consistent finding in the verification of positive sentences is that verification is faster than falsification (TA<FA). This finding is "explained" by the assumption that when we compare two representations, it is easier to identify a match than a mismatch. However, is this assumption justified? Of course we cannot answer the question unless we know the nature of mental representations of sentences and pictures. For models that propose a propositional representation, this assumption does not hold intuitively. Consider this example, are these two letter strings identical: "abcde" and "abcde"? How about these two: "abcde" and "mbcde"? Deciding that the first two strings match should take longer than deciding that the second two strings mismatch, because in the latter case, you do not need to compare all the letters. I tested this idea by asking participants to compare letter strings with the length of one, three or five. Results show that at the length of one, detecting a match is faster than a mismatch. However, at the length of three or five, detecting a match is slower than a mismatch. Although we cannot equate the comparison of letter strings with the comparisons of propositional representations, the assumption that it is faster to identify a match than a mismatch certainly merits future investigations. This result suggests at the very least that the comparison of the representations of sentences and picture is NOT like the comparison of two letter strings. It adds pressure to models that assume a comparison is performed on propositional representations.

(3)   Why do negative sentences take longer to verify than positives?

Studies show that negative sentences in general are slower to verify than affirmatives. This finding is consistent across studies, and yet no model provides a satisfactory explanation. In Clark and Chase's model, RT reflects the number of

switches of the truth index, and therefore it reflects the total number of mismatches. For example, the picture of a star on top of a cross is represented as (star above plus)$_{pic}$. Against this picture, both FA condition (plus above star)$_{sen}$ and FN condition False(star above plus)$_{sen}$ involve one mismatch, yet FA is faster than FN. Clark and Chase's model thus claims that detecting a mismatch in the positive cores is faster than detecting a mismatch in the polarity operator. As discussed in the previous point, it is unclear why this should be the case. If anything, comparing the core "star above plus" and "plus above star" seems more complicated than comparing the negation operator false and the lack of one.

In Carpenter and Just's model, the difference between FA and FN is explained by the assumption that a mismatch reinitiates the entire comparison process. For example, if the picture is red dots, represented as {RED, DOTS}, a FA sentence can be "the dots are green", represented as {GREEN, DOTS}; a FN sentence can be "the dots are not red", represented as {NEG (RED, DOTS)}. The idea is that when comparing the two inputs from inside out, a mismatch between the cores {RED, DOTS} and {GREEN, DOTS} involves only one more comparison than TA, while a mismatch between the lack of polarity marker in {RED, DOTS} and the negation marker "NEG" in {NEG (RED, DOTS)} reinitiates the comparison and thus triggers two extra comparisons. This explanation relies completely on the notation of these representations, the motivation of which is unaccounted for (see Tanenhaus et al., 1976 for a criticism on the notation system in Carpenter and Just's model). In addition, it claims that the core is compared twice when verifying an FN, and three times when verifying a TN. Not only does this process seem highly uneconomical, it should also predict that the core of a negative sentence is more activated than the core of a positive sentence as a result of the verification process. This implication is incompatible with findings of

worse memory of negative sentences relative to affirmative sentences (e.g. Cornish & Wason, 1970). Further, why should each comparison take exactly the same amount of time? If the same comparison is repeated, shouldn't subsequent comparisons be faster?

The two-step simulation account does not explain why negative sentences take longer to verify than affirmative ones. The study in Kaup et al. (2005) used a probe recognition task rather than sentence verification. In their result, reaction times to FA and FN are roughly the same. They assume that similar processes are involved in their probe recognition task and a sentence-picture verification task. However, the results from their probe recognition study didn't show slower responses to negative sentences in general than to affirmative sentences (FN=FA), yet this pattern is present in all sentence-picture verification studies. Therefore, the factors that induce longer RTs in the verification of negatives compared to affirmatives are clearly absent in the probe recognition process. Therefore, the two-step simulation account does not explain why negative sentences in general take longer to verify than positives.

Overall, although studies consistently found that verifying negative sentences is harder than verifying affirmatives, no current account provides a satisfactory explanation.

(4)   General-purpose versus particular-purpose representations:

Tanenhaus et al. (1976) pointed out that the main aim of most sentence-picture verification studies is to understand language comprehension and information processing in natural situations. However, in sentence-picture verification tasks,

participants seem to be adopting strategies that are task-specific, which tell us little about the natural language comprehension process.

If the task or context in general can influence the kind of representations that we construct, and that we have flexibility in the choice of representations for a single stimulus, how do we decide which representation model to use before assigning a representation? The only possible answer is to assume that we first process and understand a sentence and then select a model to develop a contextually appropriate representation for the sentence. Thus, "normal sentence comprehension must be prior to the first stage of these [representation] models" (Tanenhaus et al.1976: 314). In sentence-picture verification, the repetitive trials and small set of sentence and picture stimuli can allow the participants to develop a task specific representations and verification processes. After a large number of trials, participants may begin to encode the sentence and pictures immediately, partially by-passing the normal comprehension and perception processes. As training proceeds, the initial general-purpose representational processes can be replaced by special-purpose strategies specific to the task circumstances. Note that it is the initial general-purpose representation processes that are more likely to be adopted in language comprehension in natural settings. However this has largely been ignored by investigators, as many studies (e.g. Carpenter & Just, 1975; Clark & Chase, 1972)have large numbers of practice trials or pilot trials, and the data from these initial trials are generally discarded.

Taking stock, current models have limited explanatory power in the face of varying RT patterns of TN and FN from previous verification studies. With the patterns they do address, their explanations rely on the assumption that verification is faster than

falsification, and that "negation time" is longer than "falsification time". In addition, their models are unlikely to have addressed general purpose strategies adopted early in the experiments, which are the strategies that tell us more about natural language comprehension.

4.4   Introducing the dynamic pragmatic account

It seems likely that two different strategies can be used and are used in sentence-picture verification tasks. The truth-functional strategy proposed by rejection accounts can explain the polarity by truth value interaction pattern in verification tasks, but models based on this strategy lack a broader applicability in language comprehension. Generally, language is processed on the assumption that a statement is true, or at least relevant. Thus, comprehension processes are geared towards representing what is the case according to what is asserted, or what follows from what is asserted in the context. Verification is a metalinguistic task that normally requires establishing what would be the case if the sentence were true, and comparing that to evidence. The same process should be followed for both positive and negative statements. To verify a negative sentence, we will compute what the world should be like given what is asserted in the negative sentence, and comparing it with evidence. For example, if we want to verify the sentence "the clothes aren't clean", we will infer that for the sentence to be true, the clothes must be dirty. We then look for evidence that indicates dirty clothes, such as stains or odour. Based on this idea, we should not expect a polarity by truth value interaction in reaction time. Rather, we should expect that true statements, whether positive or negative, take less

time to verify than false statements[19]. This process should be the default strategy if participants apply their normal comprehension processes while performing truth-value judgement tasks, as Tanenhaus et al. (1976) suggest. This strategy can explain findings where main effects of polarity and truth value are reported. In comparison, the truth-functional strategy, proposed by rejection accounts, focuses precisely on what is not the case according to the assertion. It deviates from the natural comprehension process. Yet it is likely that this strategy can also be used, judging by the polarity by truth-value interaction that is frequently for these studies. Why and when do participants adopt the truth function strategy? I propose that the pragmatic effect of negation is the trigger.

According to the dynamic pragmatic account, when we process a negative sentence out of context, we use the fact that negation is being used as a cue that the utterance is addressing a positive QUD about the positive argument. For a sentence such as "the star is not above the plus", its prominent QUD is *whether the star is above the plus*. As we have seen in Chapter 3, the accommodation of a positive QUD incurs an extra cost. In a verification task, QUD accommodation can interfere with the verification process. The verification task poses the question of whether the sentence is true: in the case of the example the task QUD is therefore, *whether it is true that the star is not above the plus*. By the default strategy, participants infer what should follow from what is asserted in "the star is not above the plus" – i.e. *the plus is above the star*[20] - and compare this representation with the picture. However, during this

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[19]Here we assume verification is easier than falsification. The reason for this is beyond the scope of this thesis, but is discussed briefly in the "general discussions" of this chapter.

[20] Drawing this inference also requires learning and expecting that in the context of the experiment, the mentioned items can only be positioned vertically, one above the other. This information tended to be giving in the instructions in previous studies, and participants have been exposed to pictures like this in practice. However, it is likely that drawing an inference for

process, participants also accommodate the positive QUD *whether star is above plus*, the representation of which is in conflict with the sentence truth condition (*plus above star*).[21] Previous studies (Hindy et al., 2013) have shown that representing competing events simultaneously is costly. The extra cost induced by conflicting representations of questions can encourage the participants to adopt the truth functional strategy: instead of representing what should follow from what is asserted, participants can use the information from the picture to answer the accommodated positive QUD, and switch the answer afterwards. In the current example, after reading "the star is not above the plus", participants accommodate the utterance QUD, *whether the star is above the plus* as part of the normal comprehension procedure. They answer this question using evidence from the picture, and then switch the polarity of the answer to respond to the task question. Echoing Tanenhaus et al., (1976), I argue that the truth functional strategy is a special purpose process developed specifically for the task of verifying negative sentences against pictures.

The idea that the truth functional strategy is related to a contextual effect of negation has in fact been proposed by Clark (1976). He suggests that the pragmatic notion of "supposition" can explain the way a picture is coded and compared to a negative sentence. Since negative sentences are often used to deny a positive supposition, it would make sense to code the picture as the positive supposition, and compare the sentence against that supposition. Although this proposal tries to use the pragmatic effects of negation to explain the truth functional strategy, it suggests that it is the coding of the picture rather than the utterance that is influenced by the supposition of

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sentences containing such "context-dependent" binary predicates is more difficult than for sentences with natural binary predicates, such as "the door isn't open".

[21] As was proposed in Chapter 3, QUD accommodation corresponds to some kind of mental representation of the source of relevance for the utterance. I assume in this thesis that such representation is of situational content. This means, representing the QUD *whether p* can lead to the representation of properties consistent with the truth condition of *p*.

negation. Thus it cannot explain why two strategies are used in negative sentence-picture verification.

The dynamic account proposes that the default strategy for verifying negative sentences is to make inferences about what is asserted and comparing/verifying these against the picture. This is similar to the "conversion model". It thus predicts that at least at the beginning of a sentence-picture verification task, a main effect only RT pattern (TA<FA<TN<FN) is likely to occur. As the experiment proceeds, participants may adopt the truth functional strategy, which will give rise to a polarity by truth value interaction pattern (TA<FA<FN<TN). In other words, I argue that the often reported interaction in sentence-picture verification is the product of a training effect[22]. Importantly, I propose that it is the pragmatic effect of negation – the accommodation of a positive QUD – that encourages the truth functional strategy. Therefore, if we can manipulate the QUD cue or the context so that a prominent negative QUD is projected for negative sentence, the truth functional strategy should no longer develop. The following experiments test two hypotheses based on the dynamic pragmatic account of negative sentence-picture verification:

Hypothesis 1 (the training effect hypothesis): the default strategy gives rise to an initial main effect only RT pattern, and only later does the interactive RT pattern start to emerge, due to the development of the truth-functional strategy.

Hypothesis 2 (the QUD dependence hypothesis): a prominent positive QUD encourages the development of the truth-functional strategy, while a prominent

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[22] Whether and when participants develop the truth functional strategy can be influenced by many factors and are subject to individual variations. I will discuss this matter in sections 4.6 – 4.8.

negative QUD doesn't. The former gives rise to an interactive RT pattern after some training while the latter gives rise to a main effect only pattern throughout the experiment.

4.5 Experiment 1: Short experiment with natural binary predicates

In this experiment, sentences such as "the banana is/isn't peeled" are used, where the affirmative and the negative versions of the sentence imply two distinctive physical states of the subject noun. This type of predicate is different from previous sentence-picture verification studies in that they are naturally binary, i.e. the sentences themselves allow participants to infer the situations that make the sentences true, whereas previous studies either used unary predicates (e.g. the dots aren't red, Carpenter & Just, 1975) or predicates that are only binary in the context of the experiment (e.g. the star is not above the plus, Clark & Chase, 1972).

Part 1 of experiment 1 tests the training effect hypothesis. The prediction on RT of negative sentences is TN<FN initially and TN=/> FN later on. Part 2 tests the QUD dependence hypothesis. The picture context is manipulated in order to make a positive or a negative QUD more prominent. The prediction is that whether an interactive RT pattern develops depends on the polarity of the accommodated QUD.

4.5.1 Part 1: one picture context, short experiment

Method

Participants: 45 native English speakers recruited from a subject pool of University College London. Participants did not suffer from dyslexia and had normal or corrected-to-normal vision.

Materials

28 negative sentences were constructed, all of which are in the form of "the P isn't Q". All the negative sentences describe a binary property of the subject. Examples are "the door isn't shut", "the banana isn't peeled" or "the envelope isn't sealed" (Table 7). In addition, 28 positive sentences were constructed, using separate predicates from the negative sentences. Some of the affirmative control sentences have binary predicates (e.g. the truck is dirty), and others have unary predicates (e.g. the dog is eating). Every sentence is paired with one of two pictures which either matches or mismatches the meaning of the sentence. For example, "the door isn't shut" could be paired with a picture of an open door or a closed door. In total, 112 pictures are constructed (56*2). The pictures measure 300 pixels by 300 pixels. In addition, 6 sentences (3 affirmative 3 negative) and 6 pictures were constructed for practice. Half of these sentences were true against the picture.

Sentence	Picture	Correct response

The banana isn't peeled.		False
The banana isn't peeled.		True

Table 7 Example sentences and pictures: Experiment 1, one-picture context

Procedure

The experiment was conducted on a 14" laptop using E-Prime. The participants first see a sentence in the centre of the screen. They pressed the space bar once they finished reading the sentence, and a centrally located fixation cross appeared for 250ms, followed by a picture. The participants press either the "1" or "0" key to answer whether the sentence was true or false. The answer keys were counterbalanced (half the participants pressed "1" for "true" while the other half pressed "0" for true). The keys had stickers on them which says "true" or "false". The participants were told that the response accuracy and reaction time were measured, so they should make decisions as quickly and accurately as possible. There was one short break after the first 28 trials. Each participant went through 62 trials (6 for practice).

Results

As the affirmative and negative sentences do not have the same items, the results of affirmative and negative sentences are not compared directly. Instead, I focus on the results of TN and FN. Results of affirmative sentences are reported for reference. Data from 5 participants were discarded as their accuracy rate was lower than 80%.

Accuracy

The overall accuracy for all sentences (negative experimental items and affirmative controls) is 88%. The overall accuracy for negative experimental sentences is 88%. Table 8 summarizes accuracy for each condition (accuracy for affirmative controls are reported for reference). Accuracy for TN is significantly lower than FN: $t(39) = -2.14$, p(2-tailed) = 0.04. Accuracy rate did not vary significantly between the first and second half:

Accuracy	True	False
Negative experimental	0.86	0.91
Affirmative controls	0.86	0.88

Table 8 Accuracy per condition: experiment 1, one-picture context

Reaction times analysis

Reaction times were converted to Z score for each participant, and outliers were identified and eliminated using a cut-off point of 3.29 (p<0.001). In addition, reaction times smaller than 300ms or longer than 4500ms were discarded. This procedure removed 3.6% of the data. Only reaction times from correct responses

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were analyzed (this further removed 8.3% of the data). Table 9 presents the overall reaction time for each condition. RTs for affirmative controls are reported for reference. Paired sampled t-test shows that RT for FN is longer than for TN (significant by participant): $t_1(39) = -3.10$, $p = 0.004$; $t_2(27) = -1.99$, $p = 0.057$[23].

RT (ms) [24]	True	False
Negative experimental	1559	1680
Affirmative controls	1163	1303

Table 9: RT summary: one-picture context, experiment 1

Dividing responses into two halves (each with 28 trials), we can see that the difference between TN and FN is bigger in the first half than the second half (see Table 10, charted in Figure 4). To compare the difference between TN and FN in the first half with the difference in the second half, a half by truth value ANOVA showed that the interaction is not significant: $F(1,38) = 1.02$, $p = 0.3$. However, planned paired-sample t-tests show that in the first half, TN is significant faster than FN: $t(39) = -2.47$, $p = 0.018$. In the second half, TN and FN are not significantly different: $t(39) = -0.90$, $p = 0.374$. Overall, part 1 of experiment 1 suggests that when verifying negative sentences with natural binary predicates against pictures, TN is initially faster than FN, but the difference diminishes in the second half of the

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[23] Statistical tests on RT are done by participants (1) and by items (2) if possible. Generally, it is possible for overall averages, but not for RT by time intervals.
[24] Note that in the table here and in the rest of the chapters, the overall mean RT does necessarily the simple average of averages by halves, quarters or other time bins, as different numbers of incorrect responses may have been taken out in different time bins.

experiment. The lack of significant half by truth value interaction could be due to the short intervals (28 trials per half).

RT in ms	TN	FN	FN-TN
1st half	1564	1758	194
2nd half	1554	1633	79

Table 10: RT by 1st and 2nd halves: one-picture context, experiment 1
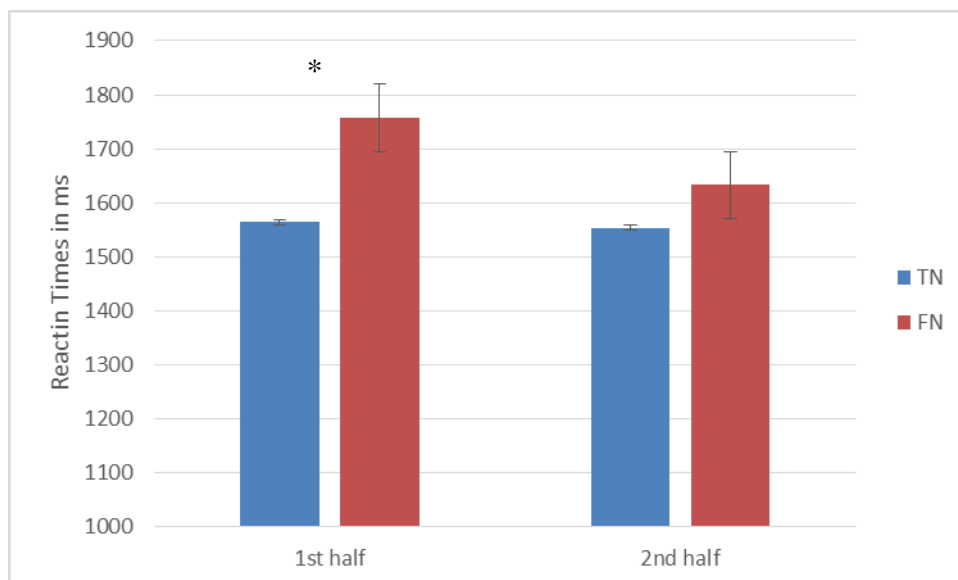
Figure 4 RT for TN and FN by halves: one-picture context, experiment 1. In this graph and in the rest of the thesis, bars indicate standard errors and asterisks indicate statistical significance (p<0.05 - *; p<0.01 - **; p<0.001 - ***).

4.5.2   Part 2: two picture condition, short experiment

In part 1 of experiment 1, we saw that in a "standard" sentence-picture verification task, participants TN was initially faster than FN, and later on TN and FN were not significantly different in reaction time. I proposed that that the main reason for this

"learning effect" is the conflict between task question and accommodated QUD for negative sentence. If we can manipulate the QUD cue or context so that the accommodated QUD is congruent with the question posed by the task, the training effect should disappear. Part 2 tests the QUD dependence hypothesis.

In Chapter 3, we saw that the cleft construction is a QUD cue. For example, a sentence "It is the banana that isn't peeled" projects the negative QUD *which one isn't peeled*. Thus, when participants verify cleft negative sentences, we should expect no training effect. To create a felicitous picture context for cleft sentences, I used visual display with two objects instead of one (see Table 11). In each display the objects were in opposite states (e.g. peeled and unpeeled).

What if participants verify *simple* negative sentences against these two-object pictures? There are two possibilities: 1) if sentential negation semantically projects a positive QUD, participants should accommodate positive QUDs based on the sentence form, in which case we should expect a training effect similar to part 1; 2) if sentential negation being a QUD cue is not hard-wired in the semantics of negation, but is sensitive to the probabilities of potential QUDs, participants may incorporate the picture context, and accommodate a negative QUD just like for cleft negatives, i.e. *which one isn't peeled*. In this case we should see that against two-object pictures, there is no training effect for either simple or cleft negative sentences.
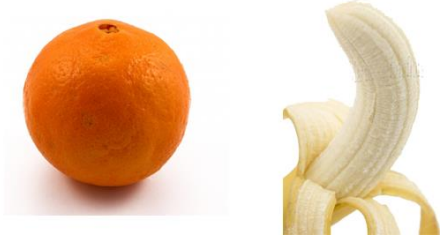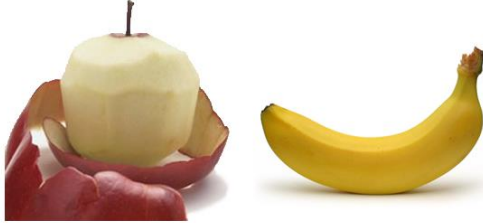
Sentence: simple / cleft	Picture	Correct response
Simple: The banana isn't peeled.		False
Cleft: It is the banana that isn't peeled.		True

Table 11 Example sentences and pictures: Experiment 1, two-picture context

Participants

50 English native speakers recruited from a subject pool of University College London. They are non-dyslexic and have normal or corrected-to-normal vision.

Materials and Procedure

The same 28 negative sentences and 28 positive controls from one picture context experiment were used. Further, a cleft version of these 56 sentences were constructed (It is P that is/isn't Q). Each sentence is paired with an image which contains a picture of the target item (e.g. banana) and an irrelevant item (e.g. apple) which can have the same property (being peeled). Only one of these two pictures matches the described property. Each experimental item generates four sentence-picture pairs (2(simple/cleft) * 2 (true/false)). In total, each participant goes through 56 trials, half

of which are negative experimental items, and half are affirmative controls. For each sentence polarity, half of the sentences are in the simple construction and half are cleft. In addition, there are 6 practice trials. The procedure is the same as part 1.

Results

Accuracy

Data from 5 participants were discarded as their accuracy rate was lower than 80%. The overall accuracy for all sentences is 90.47%, and for negative experimental sentences is 85.32%. Again, accuracy figures for affirmative controls are reported for reference. Accuracies for TN and FN are not significantly different for either simple condition: $t(44) = 0.39$, p(2-tailed) = 0.70, or cleft condition: $t(44) = 0.64$, p(2-tailed) = 0.53. Accuracies did not change significantly over the course of the experiment.

Accuracy	True	False
Negative experimental		
Simple	0.84	0.88
Cleft	0.83	0.86
Affirmative controls		
Simple	0.96	0.96
Cleft	0.97	0.94

Table 12 Average accuracy per condition: two-picture context, experiment 1

Reaction time analysis

Outliers are identified using the same procedure as part 1. Reaction times were converted to Z score for each participant, and outliers were identified and eliminated

using a cut-off point of 3.29 (p<0.001). In addition, reaction times smaller than 300ms or longer than 4500ms were discarded. RT from incorrect responses are discarded. In total, 11.15% of responses are discarded for RT analysis. Table 13 summarizes reaction times for each condition. RT for affirmative controls are reported for reference. Figure 5 plots the RT for TN and FN in simple and cleft conditions, which shows that TN is faster than FN in both simple and cleft conditions. Paired sampled t-tests show a significant difference between TN and FN in the simple condition: $t_1(44) = -2.85$, p_1(2-tailed) = 0.007; $t_2(27) = -2.27$, p_2(2-tailed) = 0.03, and in the cleft condition: $t_1(44) = -3.14$, p_1(2-tailed) = 0.003; $t_2(27) = -2.27$, p_2(2-tailed) = 0.004. There is no cleft by truth value interaction ($F_s < 0.006$, $p_s > 0.94$).

RT in ms	True	False
Simple		
Neg experimental	1789	1997
Affirmative controls	1456	1583
Cleft		
Neg experimental	1898	2168
Affirmative controls	1467	1574

Table 13 RT per condition: two-picture context, experiment 1
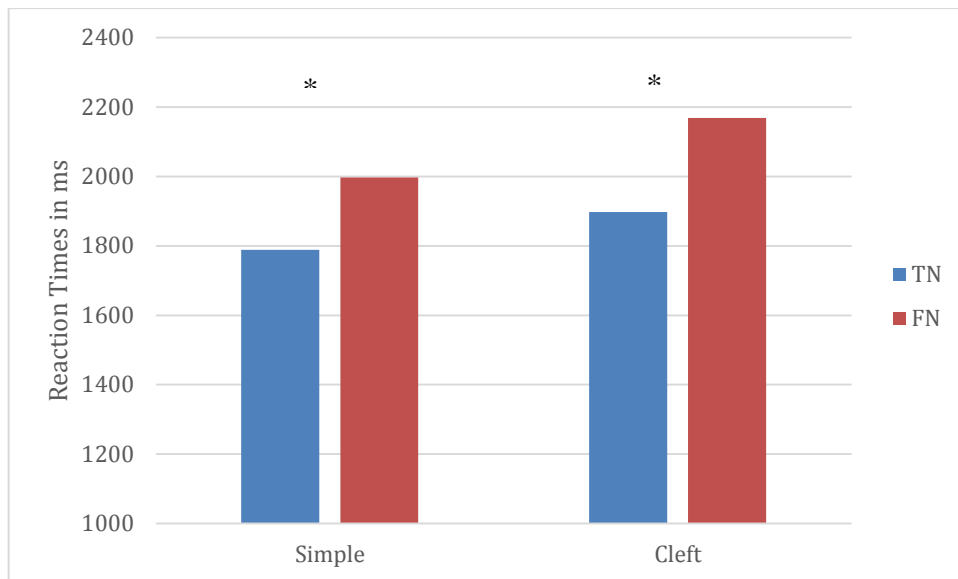
Figure 5 RT for TN and FN in simple and cleft conditions: two-picture context, experiment 1. Asterisks indicate statistical significance (p<0.05 - *; p<0.01 - **; p<0.001 - ***)

RT analysis by halves:

Table 14 summaries RT for TN and FN for the first and second halves of the experiment. Figure 6 plots these figures. Statistical analysis on RT by halves are done by participants only and not done by item (as one item can only appear in one time bin). In the simple condition, 2 (half) by 2 (truth value) ANOVA shows that there is no half by polarity interaction: $F(1,43) = 1.72$, $p = 0.20$. There is a trending main effect of half: $F(1,44) = 3.67$, $p = 0.06$, and a significant main effect of truth value: $F(1,44) = 3.67$, $p < 0.05$. Paired sampled t-tests between TN and FN in each half shows that TN is not significantly faster than FN in the first half: $t(43) = -0.84$, p (2-tailed) = 0.41; but the difference is significant in the second half: $t(43) = -3.37$, p (2-tailed) = 0.002. In the cleft condition, 2 (half) by 2 (truth value) ANOVA shows that there is no half by polarity interaction: $F(1,41) = 1.19$, $p = 0.28$. There is a significant main effect of half: $F(1,41) = 8.35$, $p = 0.006$, and a significant main effect of truth value: $F(1,41) = 10.06$, $p = 0.003$. Interestingly, cleft RT in the second

half is slower than in the first half. Paired sampled t-tests between TN and FN shows that the difference between TN and FN is trending in the first half: $t(43) = -0.1.95$, p (2-tailed) = 0.058; in the second half, TN is significantly faster than FN: $t(43) = -2.77$, p (2-tailed) = 0.008. There is no clefting x half x truth-value three way interaction (F<0.001, p = 0.97).

Overall, results in part 2 shows that when verifying simple AND cleft negative sentences against two-object pictures, TN is faster than FN, and this difference does not diminish over the course of the experiment. This result supports the QUD dependence hypothesis: whether the truth-functional strategy is developed depends on the polarity of the accommodated QUD. Interestingly, there is no difference between simple and cleft conditions, suggesting that participants incorporated the picture context and accommodated negative QUDs for simple negative sentences.

RT in ms	TN	FN
1st half		
Simple	1888	1963
Cleft	1822	2084
2nd half		
Simple	1693	2022
Cleft	1977	2235

Table 14 RT for TN and FN by halves: two-context condition, experiment 1
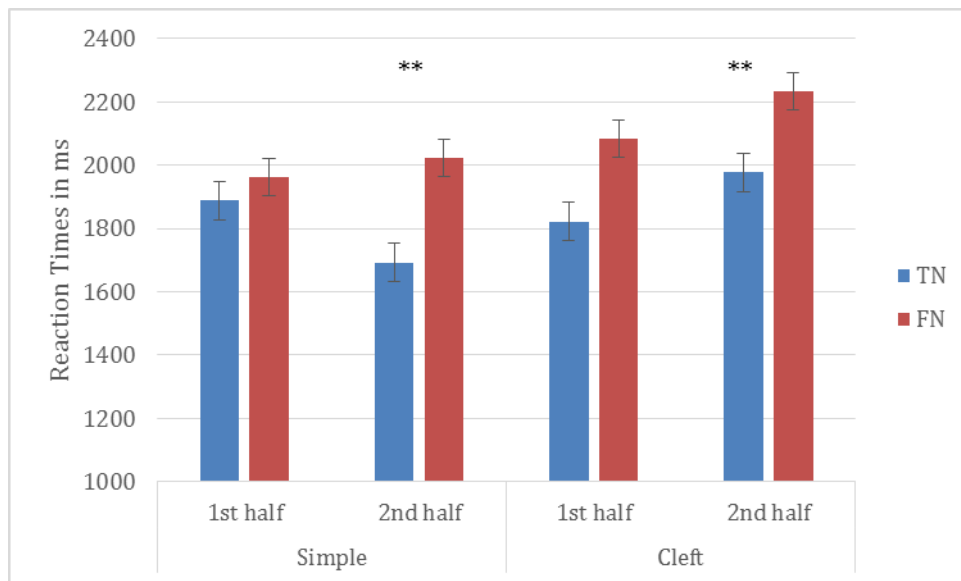
Figure 6 RT for TN and FN by halves: two-picture context, experiment 1

Discussion – Experiment 1

Part 1 tested the training effect hypothesis. The results show that when verifying negative sentences with natural binary predicates against single pictures, TN is initially faster than FN. However, this difference diminishes as the experiment proceeds. It suggests that the frequently reported polarity by truth value RT interaction is likely a result of training effect. Part 2 tested the QUD dependence hypothesis. The results show that when verifying simple and cleft negative sentences against two-object pictures, TN is faster than FN. Importantly, their RT differences do not diminish over the course of the experiment. Interestingly, there is no difference between simple and cleft conditions. This suggests that sentential negation does not mandatorily project a positive QUD, rather, the form and polarity of the accommodated QUD is sensitive to other factors (in this case, the picture context and simple salience of negative QUDs engendered by the cleft items).

Comparing part 1 with classic sentence-picture verification studies (Carpenter & Just, 1975; Clark & Chase, 1972), a main difference in the results is that in this

study, TN is not slower than FN even in the second half. A major difference in the methodology is the length of the experiment. The current study has only 58 experimental trials, while both Carpenter and Just, (1975) and Clark & Chase (1972) had over 150 trials. The difference in TN and FN results could be due to the difference in experiment length. Other factors that could contribute to a difference are the type of predicates (naturally binary vs. contextually binary (in Clark & Chase 1972) vs. unary (Carpenter & Just 1975)) and the presentation of stimuli (sequential vs. simultaneous presentation of sentence and image). To test whether the number of trials affects the manifestation of the training effect, experiment 2 repeated experiment 1 but with twice as many trials.

4.6 Experiment 2: long experiment

4.6.1 Part 1: one-picture long experiment

Participants, Materials and Procedure

44 English native speakers recruited from a subject pool of University College London. The same design as experiment 1 part 1 is used, the main difference being the number of trials in this study (56 trials versus 140 trials). A total of 56 simple negative experimental sentences and 56 simple positive control sentences were constructed. Like experiment 1 part 1, all negative experimental sentences have natural binary predicates. In addition, 28 filler sentences are added. The filler sentences have the same form as experimental sentences, half of which are negative. Each of the 140 sentences are paired with one of two single-object pictures that makes the sentence true or false, thus a total of 280 coloured pictures were constructed. After 28 sentences, there is a comprehension question. These questions

were either about the subject of the sentence (e.g. sentence: "the tennis racket is broken", question: "is the sentence about golf?" or about the predicate (e.g. "is the tennis racket broken?"). Note that comprehension questions and filler items are added so that the set-up is consistent with the two-object picture condition in part 2 Experiment 2. Data from the 29 filler items are not analysed. The procedure is the same as experiment 1.The entire experiment takes around 20 minutes to complete.

Results

Accuracy

Data from 4 participants were discarded as their accuracy rate was lower than 80%. The overall accuracy is 91.54%. Table 15 summaries the accuracy for each condition. Like experiment 1, accuracies for positive controls are reported for reference. There is no significant difference in the accuracy for TN and FN: $t_1(39) = 0.92$, $p_1 = 0.37$; $t_2(55) = 0.90$, $p_2 = 0.37$. Accuracy rate stayed stable over the trials.

Accuracy	True	False
Negative experimental	0.89	0.88
Affirmative controls	0.94	0.94

Table 15 Accuracy per condition: one-picture condition, experiment 2

Reaction time analysis

Outlier elimination is done in the same way as experiment 1. Overall reaction times for negative experimental sentences and affirmative controls are summarized in Table 16. Despite the fact that this experiment is considerably longer than part1 experiment 1, overall TN is still faster than FN: $t1(39) = -5.34$, $p1 < 0.001$; $t2(55) = -3.90$, $p2 < 0.001$.

RT in ms	True	False
Negative experimental	1354	1505
Affirmative controls	958	1091

Table 16 RT - one-picture condition, long experiment 2

To analyze RT pattern changes by time lapses, I divided the trials into four quarters (35 trials per quarter), so that the length of each training interval is comparable with the "halves" in Experiment 1. Table 17 shows how RT for TN and FN changes over time. Specifically, FN – TN numerically drops in each quarter of the trials. Interestingly, comparing RT in the 4th quarter and the 1st quarter, TN barely dropped (1323 in the 1st and 1294 in the 4th) while FN dropped by 261ms (1607 in the 1st and 1346 in the 4th). Paired-sampled t-tests on TN and FN for each of the quarter shows that TN is faster than FN in the first three quarters but in not in the last quarter. Both the t-values and significance drop gradually over four quarters. ANOVA with 2(1st vs. 4th quarter) by 2 (truth value) on between the first and fourth quarter shows a significant quarter by truth-value interaction: $F(1,39) = 2.0$, $p = 0.049$. This result fits our prediction that a polarity by truth interaction is a result of training effect.

However, the evolving RT pattern could also be due to a ceiling of improvement in RT, i.e. initially TN is much faster than FN. As training progresses, there is more room for RT improvement in FN than TN. However, if this is the reason why the main effect of truth value diminished over time, we should see a similar progression pattern in positive sentences (this is not the case as we will see in experiment 3)

RT in ms by quarters	TN	FN	FN-TN	t-test statistics	
				t value (df=39)	p value
1st	1323	1607	285	-3.45 ***	0.001
2nd	1454	1616	162	-2.74 **	0.009
3rd	1345	1435	90	-2.15 *	0.038
4th	1294	1346	52	-1.45	0.155

Table 17 RT for TN and FN over four quarters: one-picture condition, long experiment 2
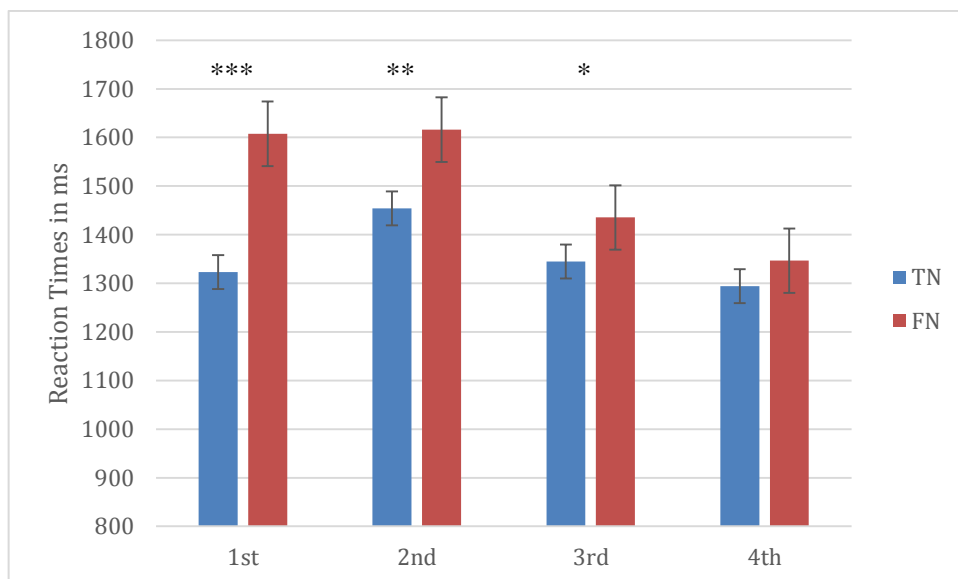
Figure 7 RT of TN and FN in four quarters - one-picture condition, experiment 2

4.6.2 Part 2: two-picture long experiment

Experiment 2 part 2 uses two-object pictures. Unlike the two-object condition in experiment 1 where cleft/ simple is an experimental variable, here only simple negatives are tested so that the results can be compared directed with the long one-object picture condition (experiment 2 part 1).

Participants, Materials and Procedure

42 native English speakers recruited from a subject pool of University College London. The design and experimental sentences are identical to part 1 experiment 2. The differences are in the pictures, filler sentences and comprehension questions. 280 coloured pictures were constructed, two for each sentence. Each picture contains two items, one of which is consistent with the property described in the predicate, while the other one isn't. The 28 filler sentences were in cleft form, half of them were affirmative and half were negative (e.g. 'It is the CD that is scratched.', 'It is the bat that isn't flying.'). 28 comprehension questions were constructed. These questions are consistent with the context which focuses on determining the item that does or doesn't have the described property. For example (Is it the bat that isn't flying?).

Results

Accuracy

Data from 2 participants were discarded as their accuracy rate was lower than 80%. The overall accuracy for all sentences is 90%. Surprisingly, accuracy for TN is significantly lower than FN: $t_1(39) = -4.79$, p_1(2-tailed) < 0.001; $t_2(55) = -4.51$, p_2(2-

tailed) < 0.001. This difference was not found in the short two-object condition (experiment 1 part 2). Accuracies did not change significantly over the trials.

Accuracy	True	False
Negative experimental	0.82	0.90
Affirmative controls	0.95	0.93

Table 18 Accuracy per condition: two-picture condition, long experiment 2

Reaction times analysis:

Outliers were eliminated in the same way as experiment 1. Overall RT and RT by quarters are summarized in Table 19. Overall, TN is significantly faster than FN. Over four quarters TN is significantly faster than FN in the 1st, 3rd and the 4th quarters. Comparing the one-picture and two-picture long study (part 1 and 2 in experiment 2), results show the difference in picture context *alone* can influence whether the truth-functional strategy is developed. In both the one-picture and two-picture conditions, TN is initially faster than FN. This difference diminishes over the four quarters of the experiment in the one-picture condition but not in the two-picture condition.

RT in ms by quarters	TN	FN	FN-TN	t-test statistics	
				t value (df=39)	p value
1st	1603	1760	157	-2.23 *	0.03
2nd	1624	1628	4	-1.09	0.28
3rd	1563	1654	91	-2.10 *	0.04
4th	1432	1583	151	-2.71 **	0.01
Total Negative	**1548**	**1651**	**106**	-3.01 **	0.005
Total Affirmative controls	**1214 (TA)**	**1390 (FA)**			

Table 19 RT over four quarters: two-picture condition, long experiment 2
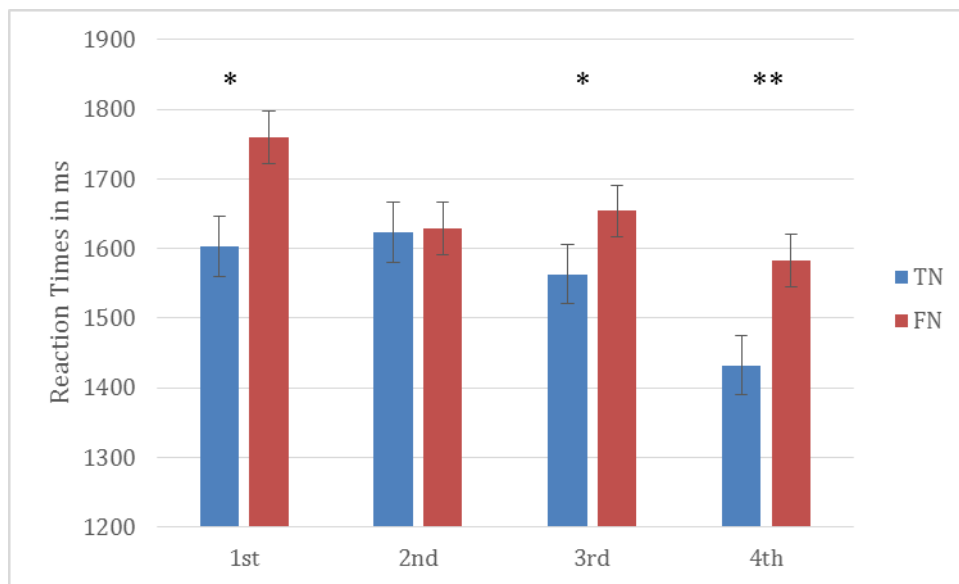
Figure 8 RT for TN and FN over four quarters: two-picture condition, long experiment 2

Before discussing the results of experiment 1 and 2, I present the last study in the

current series (verifying sentences with binary predicates). Experiments 1 and 2 used

studied the verification of negative sentences only. To better compare this study and classic ones and to compare reaction times for affirmative versus negative sentences, experiment 3 tests the verification of simple affirmative and negative sentences against one-object picture (part 1) or two-object picture (part 2).

4.7 Experiment 3: Comparing affirmative and negative sentence verification

Experiment 3 is similar to experiment 2, except that the same experimental items appear in both affirmative and negative condition. This setup allows us to compare the verification of affirmative and negative sentences. Like experiment 1 and 2, part 1 uses one-object pictures and part 2 uses two-object pictures.

4.7.1 Part 1: one-picture condition

Participants, Materials and Procedure

32 English native speakers recruited from a subject pool of University College London. Compared to experiment 2, the main difference in materials being that the same experimental items appeared in both affirmative and negative conditions. 92 items with binary predicates are created, each generates four sentence-picture pairs (2 polarities* 2 truth values). In total, each participant sees 92 experimental trials and 28 fillers (the fillers are identical to experiment 2), the polarity and truth value are counterbalanced.

Results

Accuracy

The overall accuracy is 92%. See Table 20 for average accuracies per condition. Accuracies for affirmative sentences are significantly higher than for negative sentences: $t_1(35) = 5.04$, p_1(2-tailed) < 0.001; $t_2(95) = 5.39$, p_2(2-tailed) <0.001. There is no significant difference between TN and FN ($p_s > 0.29$), or between TA and FA ($p_s > 0.17$). Accuracies did not change significantly throughout the experiment.

Accuracy	True	False
Negative	0.88	0.89
Affirmative	0.96	0.94

Table 20 Accuracy per condition: one-picture condition, experiment 3

Reaction times analysis

Overall reaction times is summarized in Table 21. There is no polarity by truth value interaction: $F_1(1,35) = 1.09$, p=0.30; $F_2(1,107) = 0.46$, p = 0.50. There is a main effect of polarity: $F_1(1,35) = 160.14$, p_1<0.0001; $F_2(1,107) = 232.41$, p_2<0.0001, and a main effect of truth value: $F_1(1,35) = 24.09$, p_1<0.001; $F_2(1,107) = 11.84$, p_2=0.001.

Accuracy	False	True
Affm	1251.44	1106.78
Neg	1644.35	1552.98

Table 21 RT for TA, TN, FA, FN - one-picture condition, experiment 3

RT analysis by quarters:

Reaction times for four quarters are summarized in Table 22. Changes in RT pattern for TN and FN resembles experiment 1 part 1: TN is initially faster than FN, but this difference shrank over the course of the experiment. On the other hand, the difference between TA and FA is stable throughout four quarters. 2(polarity) by 2(truth value) ANOVA was performed for all four quarters, which revealed no significant interaction for any of the quarters ($Fs < 4.1$, $p_s > 0.06$). This result is surprising, as we expected a polarity by truth value interaction later in the experiment.

RT per quarter	TA	FA	TN	FN
1st	993	1191	1520	1608
2nd	1009	1108	1368	1574
3rd	982	1106	1393	1475
4th	1034	1167	1493	1516

Table 22 RT per quarter: one-picture condition, experiment 3
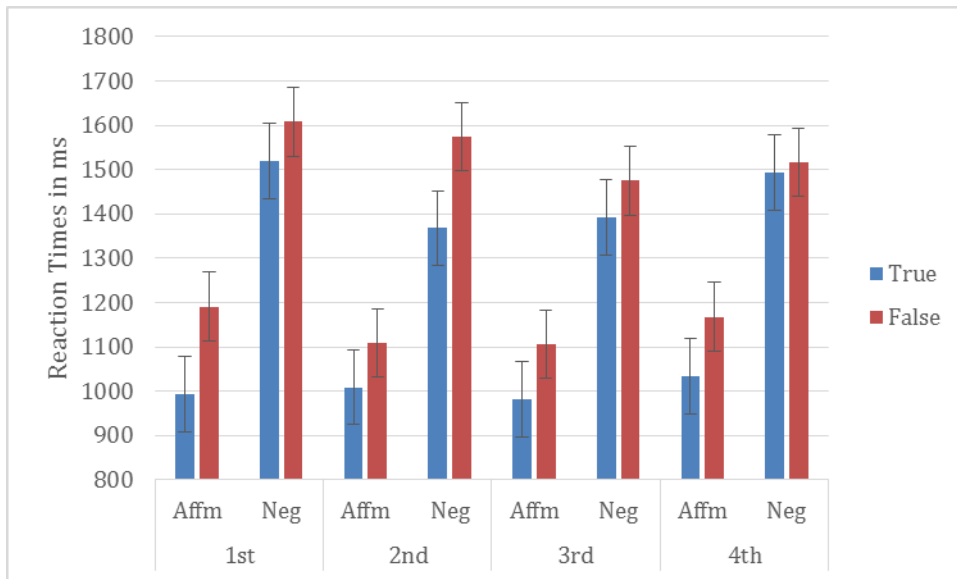
Figure 9 RT per quarter: one-picture condition, experiment 3

Given that the development of the truth functional strategy is subject to individual differences, is there a measurement that can predict whether the truth functional strategy is likely to be developed? One such predictor could be the changes in sentence reading times between early and late phases. My hypotheses states that the default strategy for verifying negative sentences is to infer what situation makes the sentence true before comparing the situation with the picture. Such an inference process should lead to a much longer sentence reading/ processing time for negative sentences compared to affirmative sentences at the beginning of the experiment. If participants develop the later developed truth conditional strategy, they should abandon the inference drawing process for negative sentences, and directly compare the picture with the accommodated affirmative QUD. Thus, if a participant develops the truth-conditional strategy, we should see a bigger drop in the sentence reading /processing times for negative sentences compared to affirmative sentences.

Based on this idea, I calculated a predictor called "N-A relative drop in reading time", which is the difference between negative and affirmative conditions in reading

time drops. Reading time drops are calculated as the average sentence reading time in the first half minus that in the second half of the experiment. I predict that participants with a large relative reading time drop are more likely to have developed the truth conditional strategy, while those with a small drop are less likely to have developed this strategy. Of course, this measurement is not a perfect predictor, as a small relative drop could be due to low reading times at the beginning of the experiment. In this case, participants might have adopted the truth functional strategy very early in the experiment. I split the participants by the median in "N-A relative drop in reading time". In the small-drop group, reading times for negative sentences sped up by 20ms relative to affirmative sentences, while in the large-drop group, the speed up was 241ms relative to affirmative sentences[25]. The reaction times for the small drop and large drop groups are summarized in Table 23, and charted in Figure 10 and Figure 11 respectively. We can see that in the last quarter, in the small-drop group TN is still faster than FN, whereas in the large-drop group, TN is slower than FN. 2(polarity) by 2(truth value) ANOVA was performed for each quarter in both the small-drop and the large-drop group (see Table 23 for F values and p values). The only significant polarity by truth value interaction occurred in the fourth quarter in the large-drop group. This result supports the idea that the change in reading times in negative sentences relative to affirmative sentences can predict whether participants developed the truth-conditional strategy for verifying negative sentences.

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[25] The average in the small drop group is very low (20ms) because some participants actually had an increase in reading times between the first and second half.

Reaction Times split by N-A relative drop in reading time	TA	FA	TN	FN	ANOVA statistics df = 15	
Small drop					F value	P value
1st	939	1122	1385	1307	4.55	0.05
2nd	1002	1067	1338	1563	2.66	0.12
3rd	945	1155	1309	1384	0.90	0.36
4th	1065	1093	1358	1508	0.74	0.40
Large drop						
1st	1042	1260	1671	1899	0.27	0.62
2nd	1016	1151	1401	1585	1.46	0.25
3rd	1029	1059	1462	1574	0.30	0.59
4th	1007	1249	1633	1523	7.11 *	0.02

Table 23 RT split by N-A relative drop in reading time: one-picture condition, experiment 1
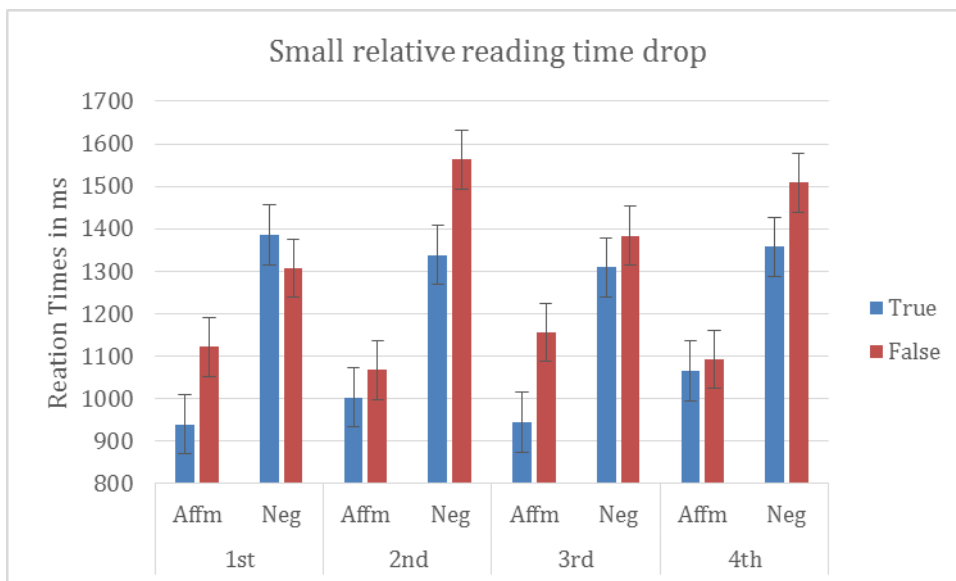
Figure 10 RT over quarters - small N-A reading time drop, experiment 3
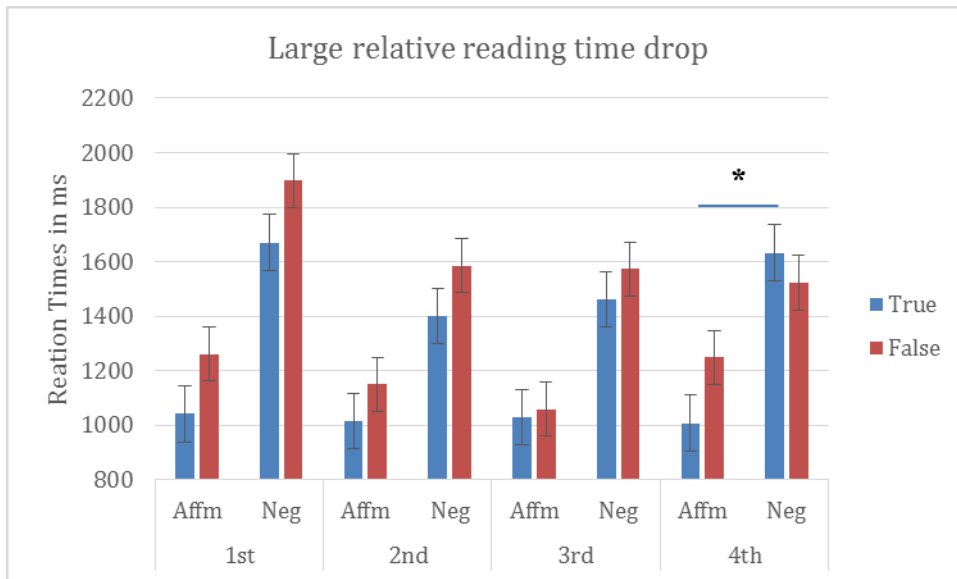
Figure 11 RT over quarters- large N-A time drop, experiment 3

4.7.2 Part 2: two-picture condition

Participants, Materials and Procedure

36 English native speakers recruited from a subject pool of University College London. The design, materials and procedure is the same as experiment 3 part 1, except that two-object pictures were used.

Results

The overall accuracy is 89%. The accuracies per condition is summarized in Table 24. The accuracies for affirmative sentences are significant higher than for negative sentences: $t_1(35) = 5.43$, p_1(2-tailed) < 0.001; $t_2(89) = 7.05$, p_2(2-tailed) < 0.001 There is a significant polarity by truth value interaction: $F_1(1,35) = 13.78$, $p_1 = 0.001$; $F_2(1, 89) = 12.98$, $p_2 < 0.001$.

Accuracy	True	False
Affm	0.95	0.91
Neg	0.82	0.88

Table 24 Accuracy per condition: two-picture condition, experiment 3

Reaction time analysis:

See Table 26 and Figure 12 for details. Overall, there is no significant (although trending) polarity by truth value interaction in reaction times, $F_1(1,35) = 3.28$, $p_1=0.08$; $F_2(1,107) = 3.19$, $p_2=0.08$. Instead, affirmative sentences are faster to verify than negative ones: $F_1(1,35) = 99.62$, $p_1 < 0.0001$; $F_2(1,107) =154.81$, $p_2 < 0.0001$, true sentences are faster than false sentences: $F_1(1,35) = 41.93$, $p_1 < 0.001$; $F_2(1,107) =26.61$, $p_2 < 0.001$.

RT	True	False
Affm	1198	1368
Neg	1599	1697

Table 25 RT: two-picture condition, experiment 3
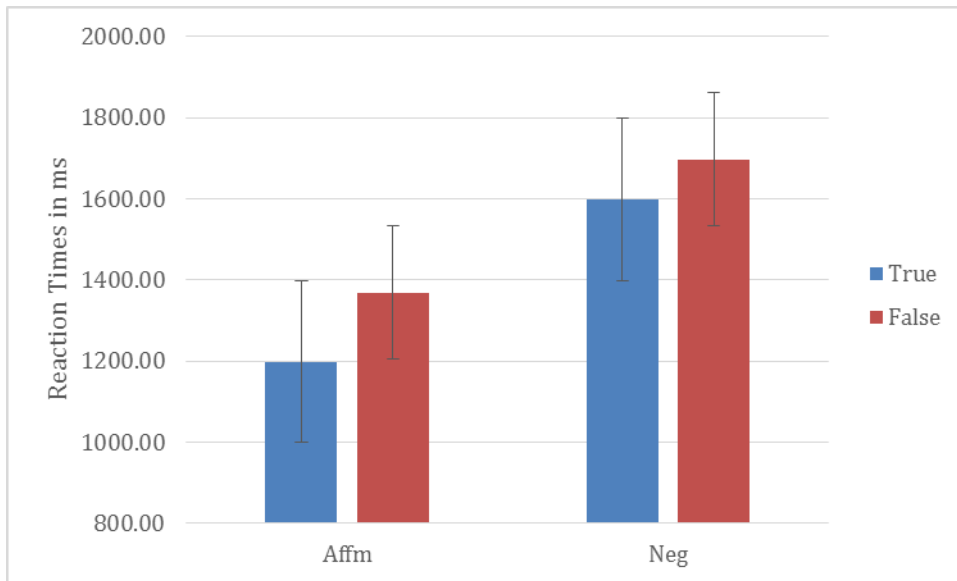
Figure 12 RT: two-picture condition, experiment 3

RT analysis by quarters:

Reaction times for four quarters (summarized in Table 26) is charted in Figure 13. Somewhat surprisingly, the changes in TN and FN is not stable over the four quarters, differing from the results of experiment 2. 2(polarity) by 2(truth value) ANOVA was performed for all four quarters, which revealed a significant interaction in the first and fourth quarters (see Table 26 for ANOVA statistics). The results suggest that some participants might have adopted the truth-conditional strategy by ignoring the un-mentioned object in the pictures.

RT per quarter	TA	FA	TN	FN	ANOVA Statistics, df = 35	
					F value	P value
1st	1265	1419	1632	1631	7.41 *	0.01
2nd	1177	1354	1651	1852	0.64	0.43
3rd	1194	1297	1553	1667	0.41	0.53
4th	1156	1427	1589	1650	8.97 *	0.01

Table 26 RT per quarter: two-picture condition, experiment 3
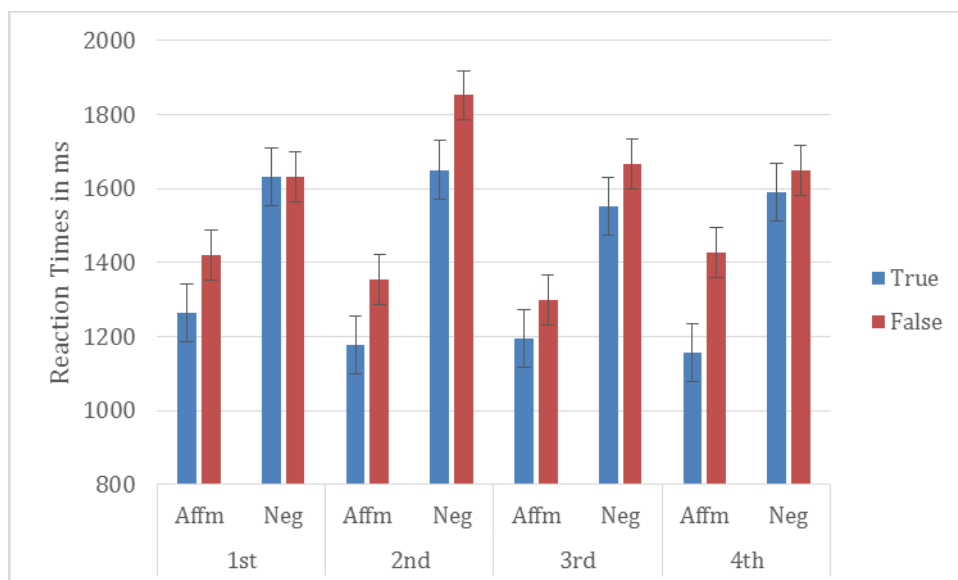
Figure 13 RT over four quarters: two-picture condition, experiment 3

4.8   Discussion experiment 1, 2 and 3

Experiments 1, 2 and 3 tested the training effect hypothesis and the QUD

dependence hypothesis using sentences with natural binary predicates. In Part 1 of

these three experiments, simple negative sentences were verified against one-object

pictures (as in part 1 of the three experiments). In this condition, TN is initially faster

than FN. As the experiment proceeds, the difference between TN and FN diminishes.

This result supports the training effect hypothesis: with the default strategy, true sentences are faster to verify than false ones regardless of their polarity. However, the truth-conditional strategy is developed that can lead to a polarity by truth value interaction in RT.

Part 2 of the three experiments test the hypothesis that developing the truth-functional strategy can be encouraged by the accommodation of a *positive* but not a *negative* QUD. I first manipulated both sentence forms and the picture context. Results from experiment 1 part 2 show that when verifying cleft negative sentences against two-object pictures, TN is consistently faster than FN throughout the experiment. Interestingly, verifying *simple* negative sentences against two-object pictures gave rise to the same result, suggesting that being a cue for positive QUD is not hard-wired in the semantics of sentential negation. Rather, the type and polarity of accommodated QUD is sensitive to contextual factors. In this case, participants incorporated the picture context, and projected negative QUDs (e.g. which one isn't peeled) just like cleft negatives. In part 2 of experiments 2 and 3, the cleft condition is removed, but cleft fillers were added to encourage participants to think about the visual images in terms of which one is different. Results continue to show that verifying simple negative sentences against two-object pictures leads to a different RT pattern from the one-object picture condition. However, participants seem to vary between accommodating a positive or negative QUD in the two-object condition, as seen in the FN-TN fluctuations in experiment 3 part 2.

Comparing negatives with positives (experiment 3 only), our results show that verifying negative sentence takes longer and incurs more errors than verifying positive sentences, which has been found in previous studies. Why do verifying

negative sentences involve more effort? I argue that the extra effort involved in the default strategy and the truth-functional strategy are contributed by different sources. With the default strategy, representing the situation that makes the sentence true requires more inferential effort for negative sentences. For example when processing a positive sentence like "the banana is peeled" we can assume that bottom-up comprehension processes activate conceptual representations for the predicates ('banana peeled') and this makes inferring the state of affairs (a peeled banana) easier than the process involved for negatives. For negatives, one must draw on extra world knowledge to infer what kind of situation might support the truth of the utterance. Drawing these kinds of inferences is one source of negative-specific cost. In addition, with this strategy, the accommodated positive QUD (e.g. *whether the banana is peeled*) is incongruent with the question posed by the task (e.g. *whether it is true that the banana is not peeled*). Participants must suppress the positive QUD (or inferences related to that) which is another source of cost. On the other hand, with the truth-functional strategy, participants do not draw inferences from negative sentences, and the positive QUD no longer needs to be suppressed. In this case, the extra effort comes from switching the response index, as suggested by the rejection models. We can see supporting evidence in the reading time changes. In experiment 3 part 1 (one-object condition), participants who have a bigger drop in reading time of negative sentences also have a more pronounced TN $<$ / $=$ FN pattern in the last quarter of the experiment, suggesting that when switching from the default strategy to the truth-functional strategy, participants save more time in the sentence reading/processing stage compared to the positive sentences by opting out from inference drawing.

Overall, the observed training effect and QUD dependence effect are incompatible with current sentence verification models. However, I also failed to replicate the classic polarity by truth value RT interaction, which suggests that how quickly participants develop the new strategy is likely to be influenced by many factors. First of all, in my experiments, natural binary predicates were used (the door isn't open -> the door is closed). Making an inference for such negative sentences should be easier than for context-dependent binary predicates (e.g. the star isn't above the plus -> the plus is above the star) or unary predicates. In the latter cases, inference drawing is not a frequent procedure and can take more effort than when the predicate is naturally binary. Secondly, in Clark and Chase (1972) and Carpenter and Just (1975), sentences were shown together with images (although participants may be instructed to read the sentence before or after looking at the image). This setup might encourage participants to develop the truth functional strategy. Studies (e.g. Hasson & Glucksberg, 2006; Kaup, Zwaan, & Lüdtke, 2006) have found that when processing negative sentences, the positive counterpart is initially represented and then deactivated. The deactivation of the positive counterpart coincides with the representation of the negation-consistent state of affairs. This deactivation process may facilitate the representation of the truth condition of the negative sentence, as the two representations are incongruent with each other. Thus, in the case of FN, if participants view the sentence (e.g. the banana isn't peeled) alongside the picture representing its positive counterpart (the banana is peeled), it is difficult to deactivate this representation, and this promotes the development of the truth functional strategy. This could explain the observation in previous studies that a sentence-first paradigm tends to get main effect only RT pattern. Experiment 4 tries to replicate Clark and Chase (1972) and tests whether the same screen display (as opposed to

sequential, sentence first display) and context dependent binary predicates encourage the development of the truth functional strategy. Experiment 5 tries to replicate Carpenter & Just (1975) to see how strategies develop when the sentence predicates are unary.

4.9 Experiment 4: Verifying sentences with context-dependent binary predicates

This experiment uses sentences and images like those in (Clark & Chase, 1972). Compared to experiment 1, 2 and 3, there are two differences: firstly, in experiment 4, sentences are presented alongside the image on the same screen, although participants were instructed to read the sentence first. As in Clark & Chase (1972), the main RT includes both sentence reading time and picture response time. Secondly, instead of natural binary predicates like "open" or "turn on", experiment 4 uses "above" and "below" in sentences which denote the relative location of two objects. This experiment is done in Chinese[26].

Method

Participants, Materials and Procedure

40 native Chinese speakers recruited from a Chinese college. All experimental sentences were in the form of "A is/isn't above /below B", with A and B denoting concrete objects such as triangle and circle. In Chinese, such sentence has a slightly different word order than in English:

35) "A (bu)zai B de shangfang/ xiamian".

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[26] It is not the aim to compare sentence verification between Chinese and English in this study.

36) A (not) locate B particle above/below.

10 pairs of experimental items were constructed, such as "triangle, circle". Each pair generated 8 experimental sentences (order of items (2) x polarity (2) x "above"/ "below" (2)). Accordingly, 10 pairs of experimental pictures were constructed. Each pair of pictures presented difference spatial relation between the two objects. All together there are 160 sentence-picture combinations. Each participant goes through these combinations twice (320 experimental trials in total). The trials are presented randomly.

The procedure is similar to experiment 1, 2 and 3. Participants are shown a sentence and a picture containing two items on the same screen. They were instructed to read the sentence first. Two keys (counterbalanced among participants) on the keyboard have a sticker each saying "yes" ("shi") or "no" ("fou"). They press one of two keys to indicate whether the sentence is true with regard to the picture. Feedback was given after each trial (correct or incorrect). There was one short break after every 32 trials. Each participant went through 326 trials (6 for practice) in total

Results

Accuracy

All participants had an accuracy rate higher than 80%. The overall accuracy was 93.33%. There is a significant polarity by truth interaction: $F(1,39)=6.38$, $p=0.016$. In addition, there is a significant main effect of polarity: $F(1,39)=48.85$, $p<0.001$. Accuracy rate stayed stable over the trials.

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Accuracy	True	False
Affirmative	0.96	0.95
Negative	0.90	0.93

Table 27: Accuracy summary: experiment 3

Reaction time analysis

Reaction times were converted to Z score for each participant, and outliers were identified and eliminated using a cut-off point of 3.29 ($p<0.001$). In addition, reaction times smaller than 1500ms or longer than 7000ms were discarded. This procedure removed 6.3% of the data. Only reaction times from correct responses were analyzed (this further removed 6.4% of the data). Below is a summary of average RT by polarity and truth value.

RT (ms)	True	False
Affirmative	2979	3167
Negative	3503	3513

Table 28 RT summary: experiment 4

Responses are then divided into eight time bins, each containing 40 trails (comparable to the length of "quarters" in experiment 2 and 3), summarized and charted below:

RT in 8 bins	TA	FA	TN	FN	ANOVA polarity by truth, df = 39		
					F	p (uncorrected)	P (Šidák corrected)
1st	3218	3432	3781	3882	2.92	0.10	0.80
2nd	3073	3185	3683	3661	2.68	0.11	0.88
3rd	2987	3271	3578	3539	9.24*	0.004	0.03
4th	2898	3122	3569	3549	1.96	0.17	1
5th	2965	3057	3510	3292	5.29	0.03	0.24
6th	2881	3083	3337	3540	0.99	0.33	1
7th	2960	3082	3263	3366	1.07	0.31	1
8th	2830	3136	3330	3319	7.00	0.01	0.08
Total	**2979**	**3167**	**3503**	**3513**	**17.9****	**<0.001**	**<0.01**

Table 29 RT by time series: experiment 4
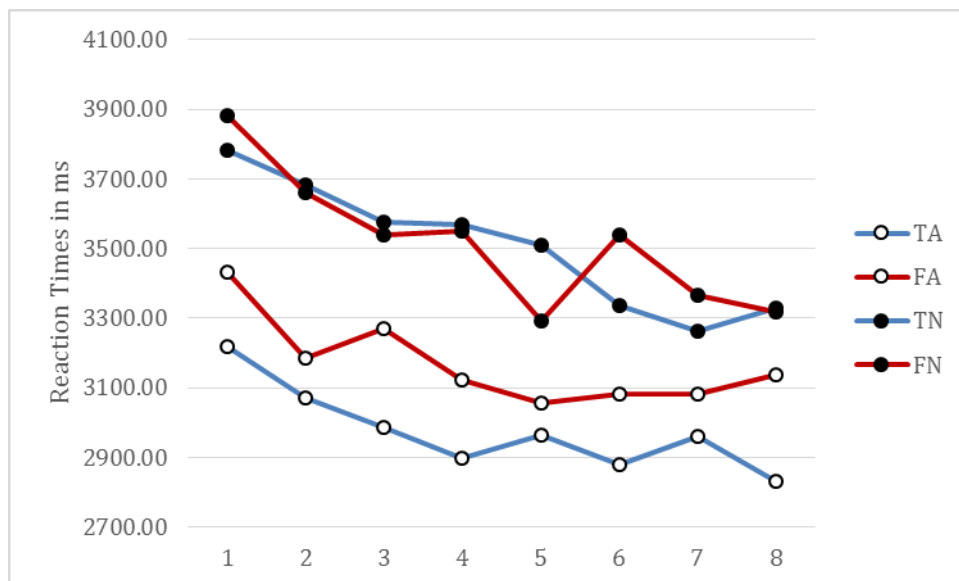
Figure 14 RT by time series: experiment 4

Over the 8 time bins, the RT patterns for TA and FA are consistent (the red line with

hollow dots is always above the blue line with hollow dots). In comparison, TN and

FN fluctuated greatly over time. Overall RT for TN is roughly the same as for FN.

2(polarity) x 2(truth value) ANOVA tests are performed on the overall RT and RT in 8 bins. Tests results are summarized in Table 29. We can see that there is a significant polarity by truth interaction overall. In the course of 8 time bins, initially there is no polarity by truth value interaction. In the first bin, TN is numerically faster than TN. However, this is not to say that the patterns show a neat main effect to interaction training effect. Rather, there were no consistent polarity by truth value patterns in the late phase of the experiment.

Discussion – experiment 4

Experiment 4 was designed to incorporate properties of the study in Clark & Chase (1972) that Experiments 1, 2 and 3 in this chapter lacked. Compared to the one picture conditions in Experiment 1 2 and 3, Experiment 4 presented the sentence and image on the same screen rather than sequential presentations. We used only one pair of prepositions in the predicates (above/below), which are only binary in the picture context. Also the sessions were much longer than experiments 1, 2 and 3. The results showed an overall polarity by truth value interaction, although TN was not slower than FN. For affirmative sentences, TA was consistently faster than FA. For negative sentences, the RT patterns fluctuated greatly. The results haven't shown a neat default strategy to truth functional strategy training effect. In the early phases, there was no polarity by truth interaction. In the mid-to-late phases, the interactive pattern was not stable.

The results suggest that participants vary in how quickly the truth functional strategy is developed. After the truth functional strategy is development, participants may come back to the default strategy. The greater fluctuations in negative sentences

compared to affirmative sentences are inconsistent with rejection models or conversion model. Rejection models should predict an interactive pattern throughout the experiment, while the conversion model should predict a consistent main effect only pattern throughout. The data supports the hypothesis that two strategies are and can be used in sentence-picture verification.

Comparing the experiment 4 with experiment 1, 2 and 3, the main difference is the overall pattern. Here TN and FN take roughly the same amount of time, while in experiment 1, 2 and 3, TN is overall faster than FN. The difference suggest that predicates that are not naturally binary (e.g. "A isn't above B") encourage the truth functional strategy more than natural binary predicates (e.g. the banana isn't peeled"). However, even with the current design, we failed to get a TN<FN RT pattern, which seems to favour the proposal that the truth functional strategy is NOT the default strategy. Rather, our proposed "default strategy" really IS the default.

4.10 Experiment 5: verifying negative sentences with unary predicates

The last experiment in this chapter uses the same materials as Carpenter & Just (1975) to investigate the development of the truth-functional strategy when verifying negative sentences with unary predicates. According to the training effect hypothesis, the default strategy involves inferring the situation that makes a negative sentence true. While this is relatively easy to do when the predicate is binary (not open => closed), it is difficult or impractical when the predicate is unary (not red => ??). Carpenter & Just (1975) used sentences such as "the dots aren't red" and pictures of dots that may be red, green or black. In this case, to infer what the dots should look like when they are not red involves deducing the complement set and representing two possible situations (dots being either green or black). Thus the default strategy

for negative sentences with unary predicates is extremely costly, and therefore the truth functional strategy is likely to develop rapidly. Experiment 4 tests this idea by looking at the RT pattern over the time course.

Methods:

Participants, Materials and Procedure

40 English native speakers were recruited from the University College London subject pool. We used sentences in the form of *"The dots are /aren't colour"*, and the colour word can be *red, black* or *green.* Three pictures of 16 dots covering 600 x 600 pixels were constructed. All dots in the picture appeared in one colour, which could be red, green or black. The background was white. There were 144 trials in total, counter balancing sentence polarity, truth value and frequency of the colour term. The procedure was the same as experiment 1, 2 and 3. Sentences were shown first, followed by a picture on the subsequent screen. The responses to the picture were recorded.

Results

The overall average accuracy is 93%. ANOVA shows that there is a significant polarity by truth value interaction in accuracy: $F(1,39) = 12.16$, $p< 0.001$. Paired-sampled t-tests show that for affirmative items, accuracies for TA and FA do not differ ($p > 0.53$); for negative items, accuracy for TN is significantly lower than for FN: $t(39) = -3.42$, $p=0.001$. The responses into four time quarters each with 36 trials, so that it is comparable to the length of time bins in previous experiments. we can see that accuracies for TA, FA and FN stay constant, the accuracy for TN dropped

over the four quarters, resulting in a significant difference between accuracies for TN and FN in the 3rd and 4th quarters (see Table 30).

Accuracy by quarter	TA	FA	TN	FN	t-test between TN and FN	
					t value df = 39	p value
1	0.96	0.96	0.91	0.93	-0.84	0.41
2	0.96	0.96	0.88	0.93	-1.35	0.19
3	0.97	0.96	0.87	0.94	-3.17	0.003
4	0.96	0.95	0.88	0.93	-2.78	0.008
Grand Total	**0.96**	**0.96**	**0.88**	**0.93**		

Table 30 Accuracy by quarters - experiment 5

RT analysis:

Mean RTs in each quarter and overall RT per condition are summarized in Table 31 and charted in Figure 15. ANOVA on overall RT shows that there is a significant polarity by truth-value interaction. In addition, ANOVA on each quarter shows that the polarity by truth-value interaction is significant in all four quarters (see Table 31 for ANOVA statistics). This shows that the truth functional strategy is adopted early on in the experiment.

Paired-sampled t-tests on TA and FA shows that TA is highly significantly faster than FA across all four quarters. In comparison, although TN is overall significantly slower than FN, in the first quarter and surprisingly in the last quarter, TN is not significantly slower than FN (see Table 31 for t-test statistics). The contrast between a stable TA vs. FA pattern and unstable TN vs. FN pattern suggests that even for

negative sentences with unary predicates, the truth-functional strategy can take some

time to develop and it might not be the only strategy used.

RT by quarters	TA	FA	Paired t-test TA vs. FA, 2 tailed		TN	FN	Paired t-test TN vs. FN, 2 tailed		ANOVA polarity by truth, df = 39	
			t	p			t	p	F	p
1st	785	1023	-8.1***	<0.001	1190	1164	0.8	0.44	25.4***	<0.001
2nd	778	939	-6.1***	<0.001	1215	1144	2.2*	0.03	25.4***	<0.001
3rd	726	977	-7.7***	<0.001	1157	1049	2.2*	0.04	29.6***	<0.001
4th	696	877	-5.8***	<0.001	1097	1027	1.6	0.12	20.9***	<0.001
Total	746	954	-10.4***	<0.001	1165	1095	2.8**	<0.01	65.4***	< 0.0001

Table 31 RT for four quarters: experiment 5
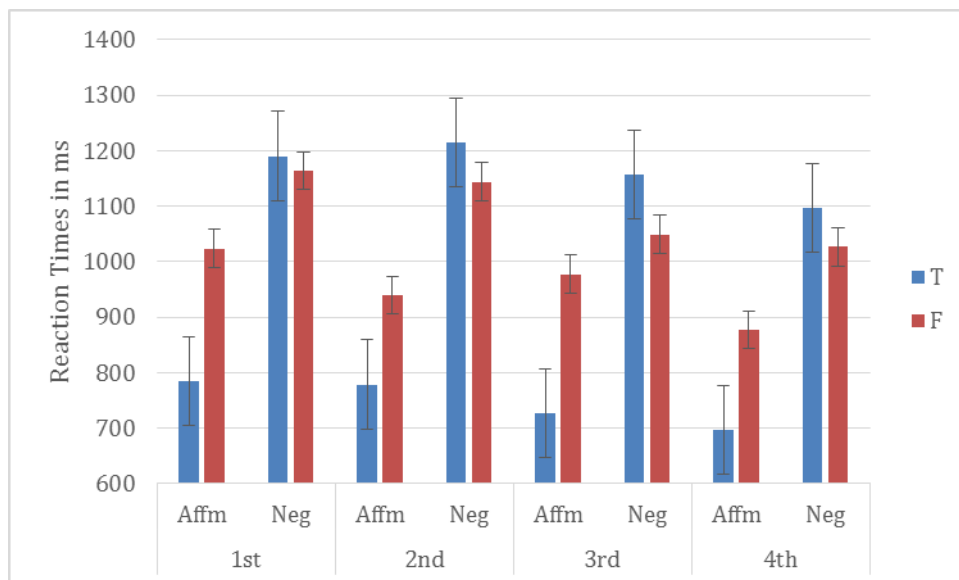
Figure 15 RT for four quarters: experiment 5

Discussion: experiment 5

Experiment 5 tested the verification of sentences with unary predicates. The results show that a polarity by truth-value interaction pattern in RT is present from early on in the experiment. While TA is faster than FA, TN is overall slower than FN, replicating results of Carpenter & Just (1975). However, TN is not consistently slower than FN over the time course. Given that the difference between TA and FA is stable and highly significant throughout the experiment, if the truth-functional strategy is the only one available, we would have seen a stable TN>FN pattern. The results thus suggest that verifying negative sentences with unary predicates encourages the development of the truth functional strategy more than verifying negative sentences with binary predicates, although participants could still use the default strategy.

4.11 General Discussion:

This chapter explores the effect of negation in sentence-picture verification tasks. Previous studies consistently found that verifying affirmative sentences is faster than verifying negative sentences, and that true affirmatives (TA) are faster than false affirmatives (FA). However, with negative sentences, findings point in different directions. While many reported TN > FN in terms of response time, some reported TN = FN, or TN < FN. Rejection accounts (e.g. Carpenter & Just, 1975; Clark & Chase, 1972) propose that negative sentences are represented as the rejection of their positive counterpart, i.e. as a positive argument embedded under the negation operator. For example, the sentence "the door is not open" is represented as "Not (the door is open)" – the rejection of "the door is open". Therefore, when verifying a negative sentence, participants first verify its positive argument and then flip the

truth index. As a result, the RT pattern for negative sentences should resemble the RT for the affirmative sentence with the opposite truth value. As TA is faster than FA, TN should be slower than FN. On the other hand, the conversion model (Trabasso & Rollins, 1971) suggests that negative sentences should be converted and represented in a positive format whenever possible. This account predicts that true sentences, whether they are affirmative or negative, should be faster than false ones. The predicate dependence model (Mayo et al., 2004) proposes that negative sentences with unary predicates are represented as a positive argument plus a negative operator, while those with binary predicates are converted to affirmative sentences. This account predicates TN > FN when the predicates are unary, and TN < FN when the predicates are binary.

I propose that two strategies can be used when verifying negative sentences against pictures: the default strategy (akin to the conversion model) and the truth functional strategy (akin to models proposed by the rejection accounts). I set out with two hypotheses on the verification of negative sentences:

Hypothesis 1 (the training effect hypothesis): the default strategy is to infer and represent the situation that makes the sentence true, and compare this representation with the evidence. This gives rise to the pattern TN<FN. As training proceeds, participants may develop the task-specific truth functional strategy, which will lead to the RT pattern TN>FN.

Hypothesis 2 (the QUD dependence hypothesis): the development of the truth functional strategy is encouraged by the accommodation of *positive* QUDs. A prominent positive QUD encourages the development of the truth-functional

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strategy, while a prominent negative QUD doesn't. The former triggers an interactive RT pattern after some training while the latter gives rise to a main effect only pattern throughout the experiment.

Five experiments were done to test these hypotheses. Experiment 1 – 3 used sentences with natural binary predicates (e.g. the banana isn't peeled). When the pictures contain a single object, TN is faster than FN in the early but not the late phase of the experiment. Overall, there was no polarity by truth-value interaction in RT; rather, we found TA<FA<TN<FN. When the pictures contain two-objects (e.g. a peeled banana and a whole orange), TN is faster than FN throughout the experiment, although in experiment 3 there were some fluctuations in the differences between TN and FN.

Experiment 4 used sentences with context dependent binary predicates (e.g. the star is not above the plus), and presented the sentences and the pictures on the same screen. The results still showed a main effect only pattern in the first 40 trials (TA<FA<TN<FN), but very quickly an interactive pattern developed. Overall, the RT pattern was TN<FA<TN=FN. Experiment 5 used sentences with unary predicates, such as "the dots aren't red" against dots in red, green or black, thus making the predicates unary. Results showed an overall polarity by truth value interaction (TA<FA<FN<TN), and the interaction pattern developed early on in the experiment, suggesting that unary predicates encourages the truth functional strategy more than binary predicates.

Overall, results from these five experiments support the training effect hypothesis and the QUD dependence hypothesis. Contrary to reported findings in Clark and Chase (1972) and Carpenter and Just (1975), in our studies, the TN > FN pattern was

difficult to obtain (found only in experiment 5), suggesting that the *default* strategy rather than the *truth functional* strategy is the favored strategy for negative sentence-picture verification.

The findings have raised questions for future research. I discuss here two questions:

(I) Individual variations: my results show that the dynamic pragmatic account cannot fully account for individual variations in strategies adopted in negative sentence verification. Time course analysis in long experiments (experiments 3, 4 and 5) shows that participants do not all first use the default strategy and then stick to the truth-functional strategy. Some participants seem to use the default strategy all the way, some develop the truth-functional strategy immediately, and some seem to be switching back and forth between the two. What factors influence individual differences in strategy development? In the two-object picture studies, while most participants seem to have used the default strategy throughout, some participants seem to have failed to incorporate the picture context and instead accommodated a positive QUD. What factors influence the projection of the prominent QUD?

(II) Why are true affirmatives easier to verify than false affirmatives? This finding has been reported in almost all previous verification studies, and has been seen consistently in the current study. Perhaps due to the intuitive nature of this effect, few theories have been proposed. Gilbert (1991) proposed that when we comprehend language, we accept or believe its content by default. Rejection comes as an effortful second step. Gilbert discussed several pieces of evidence that support this theory. The denial function of negation is one of the last linguistic abilities to be mastered by a child (Bloom, 1970). When people are cognitively deprived, they tend to accept statements unconditionally. A study by Gilbert, Krull, & Malone (1990) asked

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participants to learn fictitious vocabulary by reading sentences containing them (e.g. a monishna is an armadillo), followed by a word that informed them whether the sentence was true or false. After some trials, participants had to quickly identify a music tone, which temporarily increased their cognitive load. They found that reduced cognitive resources lead participants to believe that false statements are true, but did not lead them to believe that true statements were false. These findings suggest that rejection might involve separate cognitive processes compared to acceptance.

This idea is in line with the truth-condition theory of sentence representation (Dowty, Wall, & Peters, 1981; Johnson-Laird, 1983; Rips & Marcus, 1977). Johnson-Laird said that to comprehend a proposition one must "imagine how the world should be granted its truth" (Johnson-Laird, 1983: 110). Rips and Marcus (1977) said that comprehension of a sentence involves "creating a temporary context in which the sentence is true" (p.192). However, there is a gap between representing the sentence truth condition and believing that the sentence IS true. In sentence verification tasks, participants do have to compare the representation of the sentence against the pictures, and make a conscious decision about the sentence truth value. This idea cannot satisfactorily explain the TA<FA pattern in verification studies.

Another potential explanation is that response particles to polar questions each refer to a proposition of the relative polarity. For example, when answering "whether the banana is peeled", "yes" refers to the proposition "the banana is peeled" and "no" refers to proposition "the banana isn't peeled". To falsify a positive sentence, we need to *verify* its negative counterpart, which involves inferring the situations that makes the negative proposition true. As proposed earlier, inferring the truth

condition for a negative sentence is more costly than for a positive sentence. Overall, why verification is faster than falsification requires further research.

4.12 Conclusion

To conclude, this chapter argues that when verifying negative sentences against pictures, two strategies can be used. The default strategy is to infer and represent the situation that makes the sentence true and compare it with the evidence. In addition, participants may develop a task-specific truth-functional strategy, in which participants verify the accommodated positive QUD, and then switch the truth index. The default strategy leads to a TN < FN pattern in RT, while the truth functional strategy leads to a TN > FN pattern. The default strategy seems to be the favoured strategy during sentence-picture verification when the sentence predicates are binary. Whether the truth-functional strategy is developed depends (at least in part) on the polarity of the accommodated QUD. Only positive QUDs encourage the truth-functional strategy.

My next question is, when does QUD accommodation happen during negative sentence processing? At what point is the meaning of negation incorporated? Chapter 5 investigates the time course of negative sentence processing.

Chapter 5   The time-course of negation processing

5.1   Introduction

In chapter 1, we saw that in research into negative sentence processing, across a range of different paradigms, results very often point to the conclusion that participants represent the positive counterpart of negation while performing their task, especially in the early stages of processing. Specifically, responses in sentence verification tasks (Clark & Chase, 1972; Carpenter & Just, 1975), probe recognition tasks (Hovland & Weiss, 1953), ERP studies (Fischler, Bloom, Childers, Roucos, & Perry, 1983; Lüdtke, Friedrich, De Filippis, & Kaup, 2008) and mouse-tracking tasks (Dale & Duran, 2011) strongly suggest that a representation the positive counterpart of negation is employed in the process. For example, in probe recognition studies Kaup et al. (2006, 2007) found that after reading a negative sentence such as "the bird was not in the air", participants responded faster to an image of a flying bird than one of a bird at rest at 250ms ISI but not at 1500ms ISI. A study by Hasson and Glucksberg, (2006) on the processing of negative metaphors found that 150ms or 500ms after reading a negative sentence like "this lawyer is not a shark", participants were faster at making a lexical decision on a probe related to the positive counterpart (vicious) than one that is related to the negative sentence meaning (gentle). At 1000ms, the pattern is reversed. They conclude that negations are initially represented as their positive counterpart, and it takes between 500ms to 1000ms to arrive at the negation-consistent meaning.

While it seems that participants do sometimes represent the positive counterpart to complete these tasks, many studies suggest that they do not always. In the ERP

literature, Nieuwland & Kuperberg (2008) show that contextually felicitous True Negatives do not give rise to an N400 effect compared to either True Affirmatives or False Negatives. Similarly, Dale & Duran (2011, Experiment 2&3) indicate that the more contextual support the negatives sentences have, the less the tendency to consider the positive counterpart. fMRI studies on negation (Tettamanti et al., 2008; Tomasino, Weiss, & Fink, 2010) show that while reading a positive sentence with action verbs (e.g. 'grip', 'clasp') activates the motor brain regions, negation modulates this activity. Specifically, negative sentences tend to show decreased activation relative to positive counterparts. Finally, I have shown in Chapter 3 that when we change the negative sentence form but not the propositional content, participants no longer respond faster to the picture consistent with the positive counterpart. 250ms after reading a cleft negative sentence such as "It is John who hasn't ironed his shirt", participants responded faster to a picture consistent with the negative sentence meaning (crumpled shirt) than a picture consistent with the positive counterpart (ironed shirt). I argued that the change of linguistic form to a cleft sentence causes a change of accommodated QUD from positive to negative.

Why is the positive counterpart often represented during negation processing? As discussed in Chapter 1, there are two perspectives in the literature: rejection accounts and contextual views. Rejection accounts draws from the function of negation as an external truth-function operator. Negation reverses the truth value of its embedded proposition. Based on this function, rejection accounts state that a negative sentence is represented by multiple constituents, namely the negation operator and its positive argument. In the course of sentence comprehension or verification, participants first represent the embedded argument, and then reject it or reverse its truth value. Both

propositional theories (Clark & Chase, 1972; Carpenter & Just, 1975) and the two-step simulation theory (Kaup, Zwaan, et al., 2007) follow the idea of "rejection", although they differ in how the constituents are represented. These theories explain why the positive counterpart is activated in the first place and that this is the cause of the extra difficulty of negation which is often reported in the psycholinguistics literature. They also claim that processing is initially insensitive to negation. By contrast, the contextual perspective, stemming from Wason (1965), suggests that with the right kind of contextual support, negative sentences are not difficult. In this tradition, Nieuwland and Kuperberg (2008) suggest that, with the right contextual support, the positive counterpart need not be represented for comprehension. Similar conclusions are drawn in Dale & Duran (2011). Contextual views explain why the positive counterpart is sometimes not activated when processing a negative sentence.

What seems to be missing from the contextual perspective is an explicit account of why the positive counterpart is sometimes represented when we process negative sentences. This is provided by the dynamic pragmatic account: the positive counterpart of a negative sentence is sometimes represented due to QUD accommodation. I argued in Chapter 2 that negation is a cue for retrieving a prominent positive QUD. Without other relevant cues or context, participants processing a negative sentence *not p* infer that the most likely QUD is *whether p*. For example, for a simple negative sentence such as "John hasn't ironed his shirt", its most prominent QUD is whether John has ironed his shirt. As most studies presented participants with sentences without context, they reported the representation of the positive counterpart when processing a negative sentence because of the accommodation of a positive QUD. However, if the linguistic form of a negative

sentence or some features of the context project a negative QUD, participants will no longer represent the positive counterpart. For example, for a cleft negative sentence "It is John who hasn't ironed his shirt", the most prominent QUD is "who hasn't ironed their shirt". In this case, comprehenders do not first activate the representation of an ironed shirt.

5.2   The Current study

The current study investigates *when* QUD accommodation occurs, and *at what point* the meaning of negation is incorporated. We compare the time course of representations during the processing of positive and negative sentences, using a visual world eyetracking paradigm.

Prior studies in visual world eyetracking found that even without any metalinguistic task, participants shift their visual attention around the scene as the linguistic stimuli unfold (Altmann & Kamide, 2007; Altmann & Steedman, 1988; R.M. Cooper, 1974; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995; for a comprehensive review on the visual world paradigm, see Huettig, Rommers, & Meyer, 2011). Altmann and colleagues (G. Altmann & Kamide, 1999, 2007) found evidence that language-mediated eye movements are anticipatory, and they correspond to a dynamically changing representation of events. Altmann et al. (2007) presented participants with semi-realistic visual scenes such as a man standing next to a table with an empty wine glass, a full beer glass and some distractors, while listening to a sentence such as "the man will drink all of the beer" or "the man has drunk all of the wine". They found that participants shifted their visual attention to the full beer glass or empty wine glass before the onset of the critical noun "beer" or "wine". Follow up

studies, such as in Altmann & Kamide (2007) show that eye-gaze around visual scenes is driven by more than low-level associations between lexical items ('eat') and images (of edible objects). In Altmann & Kamide (2007), participants hear sentences like, 'The man will drink all of the wine' or 'The man has drunk all of the beer'. The visual display contains a full glass (of wine) and an empty beer glass among other distractors. Altmann & Kamide show that participants' gazes favour the full glass in the future tense condition and the empty glass in the perfect tense condition. This shows that participants incrementally update their representation of events by composing the meaning of the tense (future vs. perfect) with the verb.

This paradigm provides us with a tool to study the time course of the processing of negative sentences compared to their positive counterparts. If the negative particle 'not' is processed on line by composing its meaning with the meanings of the noun phrases and verbs around it in the sentence, we should see evidence for this in where participants look around a visual scene. This paradigm should provide insight into whether participants first represent the positive counterpart of negation, under what conditions they do so, and for how long. Specifically, we are interested in if, when, and for how long the representation of the positive counterpart is activated when hearing a simple negative such as 38b), or a cleft negative such as 39b). Also we want to see if the processing of simple and cleft negative sentences are delayed compared to their positive counterparts such as 1) and 39), and at what point is the meaning of negation integrated.

38a)   John has ironed his brother's shirt.

38b)   John hasn't ironed his brother's shirt.

39a)   It is John who has ironed his brother's shirt.

39b)   It is John who hasn't ironed his brother's shirt.

Positive sentences like 38a) and 39) imply that the current state of the shirt is smooth, while their negative versions 38b) and 39b) imply that the shirt is crumpled. Following Altmann and Kamide (2007), in the current study, participants hear sentences while looking at a visual scene containing the representation of the implied state (the target) and the representation of the opposite state (the competitor). According to rejection accounts, both 38b) and 39b) should be processed by first representing the positive argument (John has ironed his brother's shirt), thus predicting a delayed gaze to target in 38b) relative to 1), and similarly in 39b) relative to 39a)39). For both 38b) and 39b), attention should first be directed to the representation of the positive argument (competitor), before being shifted to the target. However, the dynamic pragmatic account predicts a delay in 38b) relative to 1), but reduced or no delay in 39b) relative to 39a).

5.3   Methods

Participants

Thirty-six participants between the age of 19 and 36 were recruited from University College London via an online psychological subject pool, 20 were female. They participated either for course credit or £4. All participants speak English as a native language. They have uncorrected or corrected to normal vision.

Materials

This experiment has a two by two within participant design. The two independent variables are polarity and cleft-ness. These two variables generate four experimental conditions: simple affirmative, simple negative, cleft affirmative and cleft negative. 40 experimental items were constructed. The predicate of an experimental sentence always implies that the item is in two different states before and after the event. Experimental sentences are in the form of "(It is) *Name* (who) has/hasn't *verb* his/her *someone's noun"*. For example, "Matt hasn't shut his dad's window" (simple) or "It is Matt who hasn't shut his dad's window" (cleft). Note that we added words such as "his dad's" in between the verb and target noun, because studies (Altmann & Kamide, 2007 experiemnt 1; Barr, 2008) have shown that upon hearing a word, the semantic priming effect can temporarily interfere with the integration of linguistic stimuli with anticipatory event representation or contextual information.

Each experimental item generates four sentences. Four lists were created, each containing 40 experimental sentences. Each item only appears once in a list. In addition, there are 40 fillers, among which half were affirmative, half were negative. Half indicate the beginning state of an event (*will* and *should have)*, while the other half indicate the end state of an event (*shouldn't have*). After 20 sentences (10 experimental), there was a comprehension question. The aim was to check whether the participants understood the content of the sentence. For example, for filler "Tom has fixed his uncle's fridge", the question was "is Tom's uncle's fridge still broken?" Each participant heard 80 sentences (see Table 32 for examples).

Exp./Filler	Condition	Cleft	Number of items	Example
Exp.	has	simple	10	Anna has closed her mom's umbrella.
	hasn't	simple	10	Matt hasn't shut his dad's window.
	has	cleft	10	It is James who has blown up his cousin's balloon.
	hasn't	cleft	10	It is Lilly who hasn't cracked her sister's egg.
Filler	will	simple	5	Bob will chop his father's wood.
	will	cleft	5	Andrew will ride his father's horse.
	should have	simple	5	Bill should have wrapped the birthday present.
	should have	cleft	5	It is Lucy who should have watered her Dad's flower.
	shouldn't have	simple	10	Eva shouldn't have scratched her brother's CD.
	shouldn't have	cleft	10	It is Betty who shouldn't have cut her friend's rope.
	Total		**80**	

Table 32 Design and examples of experimental and filler sentences

Sentences were recorded by a male speaker of Southeast British English. The speaker was instructed to read all sentences with a natural intonation, while putting a stress on "has" or "hasn't" for simple sentences, and on the name (e.g. John) for cleft sentences. Note that in cleft sentences, "hasn't" received a secondary stress, but "has" did not. This was not instructed.

Each experimental item and each filler sentence is paired with a visual scene consisting of five items: a person (which matches the gender of the name), two critical images and two distractors (see Figure 16 for an example). The two critical images include a target and a competitor. The target represents the implied state of the item, while the competitor represents the opposite state. For example, for the sentence "Matt hasn't shut his dad's window", the target is an open window and

the competitor is a shut window. The target for a negative sentence is the competitor

for the positive counterpart. The two distractors are images of an item in two states

(for example a plain bagel and a bagel with cream cheese), so that participants will

not be able to predict the verb before hearing it. All pictures of the person measures

150*250 pixels. All pictures of four items measure 250*250 pixels. The screen

resolution is 1024 * 768 pixels. The picture of the person is always in the centre of

the screen. Target, competitor and two distractors are located in the four corners of

the screen but the exact location of each is random.

Figure 16 Example visual scene

Procedure:

The experiment was conducted using E-Prime software and a Tobii X60 eye-tracker.

Participants were calibrated at the beginning of the experiment. Head movements

were not restricted but participants were asked to stay still as much as possible for

the duration of the experiment. Before each trial, there was a fixation cross in the centre of the screen, and participants' eye gaze had to be identified for a continuous 3 seconds before the trial started. Then a scene with five images appeared on the screen. Participants had one second to preview the images, and the audio stimuli started after the preview. During the audio, the participants were instructed to simply listen and look at the images. The sentences last an average of 3.04 seconds (standard deviation 0.37 seconds. Minimum length 2.31 seconds, maximum length 4.35 seconds). Eye movements were recorded for 6 seconds for each trial. For 20 out of 80 sentences, a comprehension question appeared on the screen after the sentence, and participants pressed either the "yes" or "no" key to answer the question (they are 1 and 0, with stickers which says "yes" or "no"). The whole experiment lasted approximately 25 minutes.

5.4   Data Analysis and Results

5.4.1   Analysis of audio stimuli

The onset and offset for each word in every experimental audio stimulus is hand marked using phonetics analysis software Praat (Boersma & Weenink, 2013), with a millisecond resolution. For the analysis, we are interested in the main verb, post-verb silence, possessive pronouns ("his" or "her"), second possessive, such as "brother's" or "friend's", and the final noun. Table 33 shows the mean and standard deviation of duration for each of these words in milliseconds.

Average word length in ms	verb	post-verb silence	his/her	someone's	noun
Simple					
Has	504	222	169	424	546
Hasnt	501	151	169	441	577
Cleft					
Has	438	10	174	420	549
Hasnt	467	38	175	419	578

Table 33 Average word lengths in ms for key regions

Between positive and negative simple sentences, there is no significant difference in the duration of verb (t=0.34, p=0.74), "his"/"her" (t= -0.16, p=0.87), someone's (t=-1.96, p=0.06), or noun (t=-1.83, p=0.07). There is a significant difference in the duration of post-verb silence (t=2.98, p=0.02).

Between positive and negative cleft sentences, there is no significant difference in the duration of "his"/"her" (t=-0.17, p=0.87), or "someone's" (t=0.22, p=0.83). However there is a significant difference in the duration of verb (t=-2.65, p=0.01), in post-verb silence (t=-0.25, p=0.02), and in noun (t=-0.25, p=0.01).

Comparing simple and cleft sentences, there is a significant difference in the duration of verb. On average the verbs in simple sentences are 49 ms (t=-6.23, p<0.001) longer than cleft. Post-verb silence in simple sentence is 158 ms longer than in cleft (t= - 11.78, p<0.001). There is no significant difference in the duration of "his"/"her" (t= 1.35, p=0.18), someone's (t=-1.94, p=0.06), or noun (t=0.21, p=0.84).

5.4.2   Analysis of eye-movements – main analysis

Fixations that landed within the coordinates of the target and competitor are analyzed against key time periods in the audio stimuli. Fixations that landed within the coordinates of two distractors and the image of the person are also extracted. Any fixations deemed invalid due to blinking or head movements were removed. Any fixations shorter than 80 ms were excluded, as extremely short fixations are often due to false saccade planning (Rayner & Pollatsek, 1989). Table 34 summarizes the percentages of looks to each area across different word regions.

We are interested in the anticipatory looks to the target compared to the competitor after the verb. I calculated natural log ratio of percentage of looks to target over competitor: Ln ($P_{target}/P_{competitor}$). "Ln" refers to natural log, P_{target} refers to the percentage of looks to target image, and $P_{competitor}$ refers to the percentage of looks to the competitor image. When the log ratio is 0, there is equal percentage of looks to target and competitor. When the log ratio is above 0, there is a bias towards target, and when below 0, there is a bias towards competitor.

Figure 17 (simple) and Figure 18 (cleft) plot the log ratios in 17ms increments (the eye tracker runs at 60Hz), from the verb to the end of the sentence. Figure 19 (simple) and Figure 20 (cleft) plot the percentages of looks to the target and the competitor. With regard to the example sentence "(It is) Matt (who) hasn't shut this dad's window", the graphs covers before, during and after the section "shut his dad's window". The regions are named as *verb, [pause], his, someone's,* and *noun*. The average onset and offset of key regions are marked with vertical lines. Note that for all plots and data analysis, word regions have been offset by 200ms, as it takes

around 200ms to launch an eye-movement (Hallett, 1986). As sentences differ in their onsets and offsets of words, the curves in all figures are resynchronized at the onset of each word, so that the graph more accurately reflects the evolving visual biases relative to the audio stimuli (Altmann & Kamide, 2009).

Percentage of looks by condition		verb	[SIL] & "his/her"	someone's	noun
	target	0.13	0.25	0.32	0.35
	competitor	0.13	0.13	0.13	0.16
Simple Positive	target & competitor Total	**0.26**	**0.38**	**0.45**	**0.51**
	person	0.29	0.2	0.16	0.14
	distractors	0.25	0.24	0.23	0.16
	target	0.15	0.21	0.27	0.32
	competitor	0.11	0.21	0.2	0.2
Simple Negative	target & competitor Total	**0.26**	**0.42**	**0.47**	**0.52**
	person	0.28	0.19	0.18	0.14
	distractors	0.25	0.21	0.18	0.16
	target	0.13	0.14	0.24	0.38
	competitor	0.12	0.14	0.17	0.16
Cleft Positive	target & competitor Total	**0.25**	**0.29**	**0.41**	**0.54**
	person	0.3	0.28	0.23	0.14
	distractors	0.29	0.25	0.2	0.15
	target	0.14	0.2	0.26	0.31
	competitor	0.15	0.2	0.19	0.19
Cleft Negative	target & competitor Total	**0.29**	**0.4**	**0.45**	**0.5**
	person	0.24	0.23	0.17	0.13
	distractors	0.28	0.2	0.19	0.18

Table 34 Percentage of looks to target, competitor, person and distractors for all conditions in key regions
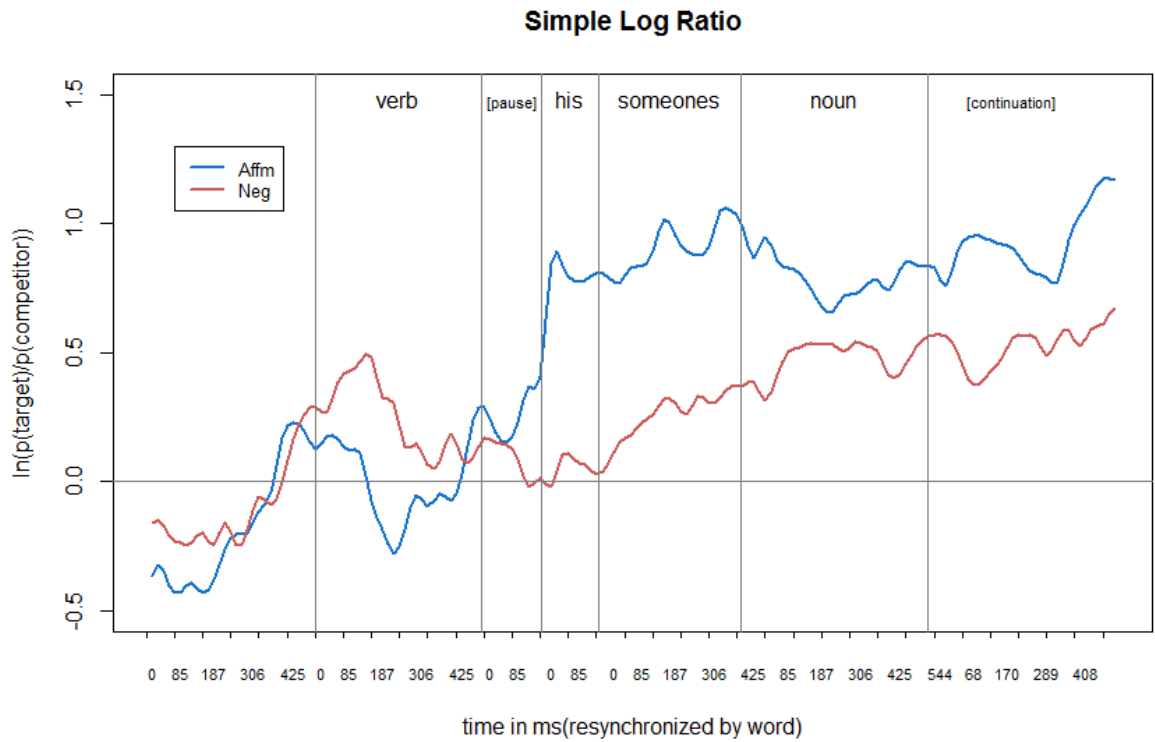
Simple Log Ratio

Figure 17 Log ratio of percentage of looks to target over competitor for positive and negative conditions - simple
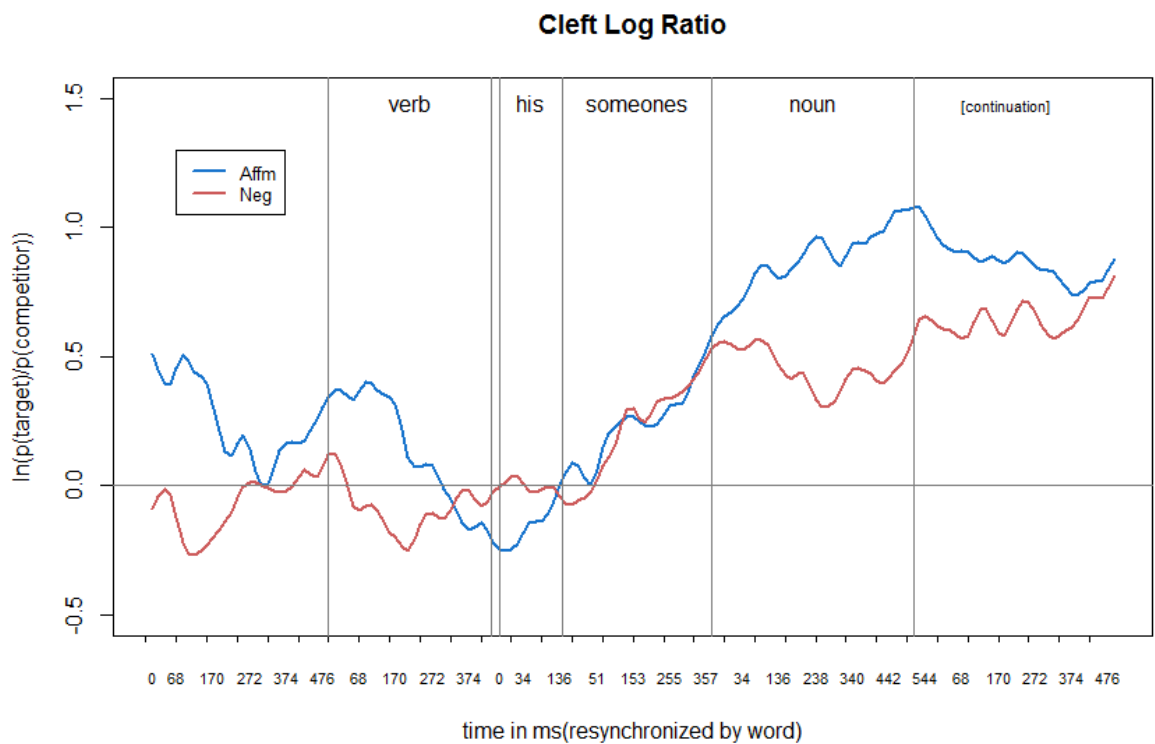
Cleft Log Ratio

Figure 18 Log ratio of percentage of looks to target over competitor for positive and negative conditions - cleft
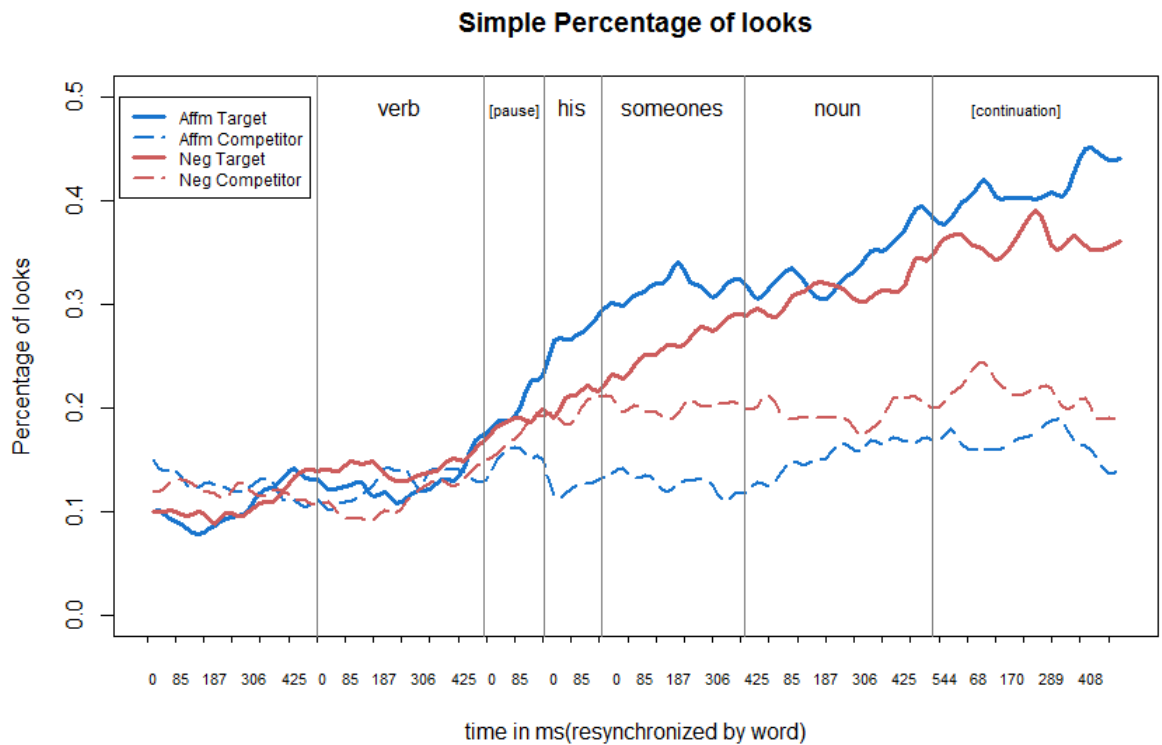
Figure 19 Percentage of looks to target and competitor for positive and negative – simple
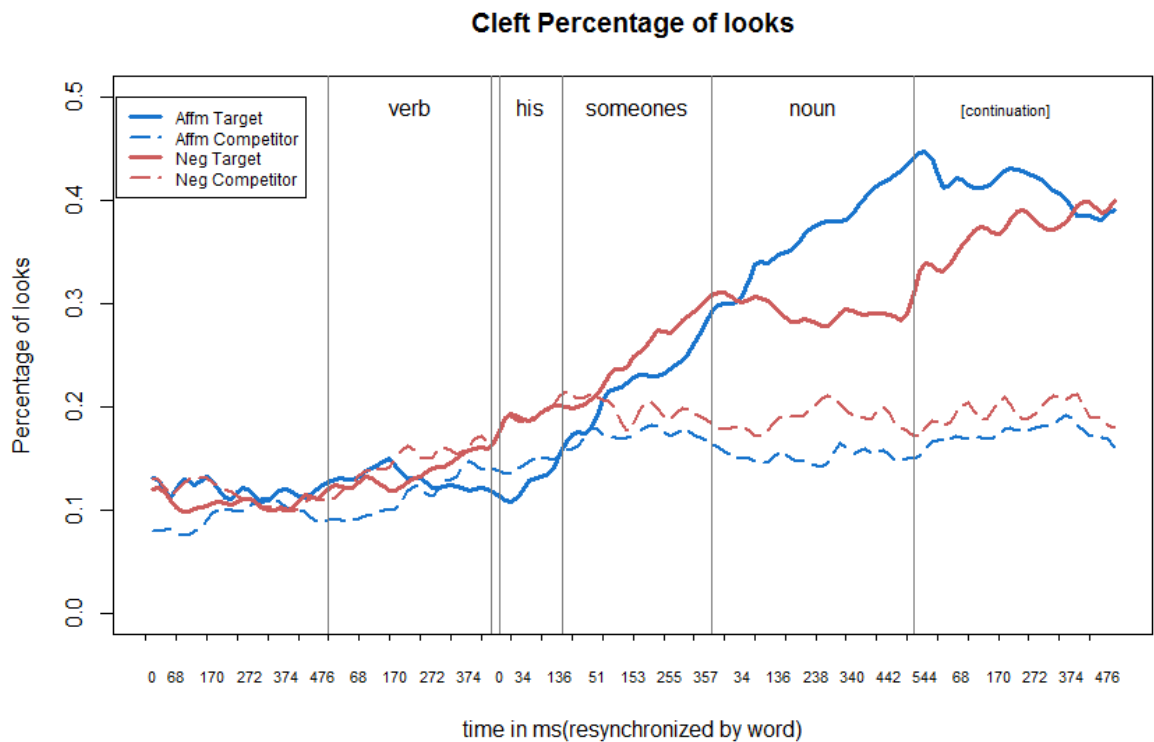
Figure 20 Percentage of looks to target and competitor for positive and negative - cleft

I averaged the target over competitor log ratios in key regions both by participant and

by item. Statistical tests are applied on these average log ratios. Note that both P_{target}

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and $P_{competitor}$ have a distribution over a closed interval of [0,1]. When either measurement is 0, it is a problem for log transformation. In this case, I transformed 0 values using the function $y'' = [y(N − 1) + s]/N$ (Mckinstry et al., 2008). y'' is the transformed value, y is the original value. N is the sample size and s is a constant between 0 and 1. From a Bayesian point of view, s acts as if we are taking a prior into account. 0.5 is recommended as a reasonable choice for s. This function "squeezes" the values into an open interval (0,1).

Let us inspect the results in the graphs. For simple sentences (Figure 17) there is a difference in log ratios between positive and negative from the offset of the verb to the offset of the noun. For positives, a bias towards target was formed immediately after the verb. For negatives, however, there are a roughly equal amount of looks to the target and the competitor after the verb, in the "post-verb silence and his" regions. A target bias was developed later, but nevertheless before the onset of the noun. We can see the patterns from a different point of view in Figure 19 which plots percentages of looks to the target (solid line) and the competitor (dotted line) for simple sentences. For positives (blue), looks to the target but not the competitor rise after the verb. The two blue lines diverge at around the offset of the verb. For negatives (red), looks to both the target and the competitor rise after the verb. This indicates that negation triggers an inference from the positive counterpart. However, participants did not first focus on the competitor and then shift their attention to the target. Paired sampled t-tests on log ratios show that there is a significant difference between positive and negative in "post-verb silence and his" region, "someone's" region and noun region (see Table 35).

In the case of cleft sentences (Figure 18), there is no difference in log ratios between positive and negative from the offset of verb to the onset of noun. In this region, participants were paying comparable attention to the target and the competitor. Percentage plot for cleft (Figure 20) shows that for both positive and negative, looks to target and competitor diverge after the offset of "his". Paired sampled t-tests on log ratios (see Table 35) show that there is no difference between positive and negative in "post-verb silence and his" region and "someone's" region. In the noun region, the difference is significant by subject only.

Comparing simple and cleft sentences, between the offset of verb and the onset of noun, there is a difference between positive and negative for simple but not cleft sentences. In order to test whether this interactive pattern is significant, we need to extract a fixed length window from the offset of verb for both simple and cleft sentences. This is because the post-verb silence region for cleft is shorter than that for simple by 160ms, thus regions defined by word boundaries are not ideal for comparison between simple and cleft, as different amounts of time elapsed after the verb. I therefore extracted a 449ms window from the offset of verb for all items. This is the shortest gap between the offset of verb and the onset of noun among all items. As before, I calculated the average natural log ratio of percentages of looks to target over competitor in the post-verb 449ms window. I performed a cleftness (2) by polarity (2) ANOVA, which shows that there is a significant cleftness by polarity interaction. $F_1(1,35)=8.19$, p=0.007. $F_2(1,38)=6.16$, p=0.018.

Finally, in order to determine whether there are significantly more looks to the target than the competitor, i.e. whether the averaged log ratio is significantly bigger than zero, I performed one-sampled t-tests comparing log ratios with zero for key regions

(Table 36). We can see that for cleft sentences, positive and negative show similar patterns. Bias to target is significant in "someone's" and noun regions. For simple sentences, positives show a significant bias to target immediately after verb. For negatives, bias to target only becomes significant in the "noun" region.

In addition to comparing looks to the target versus the competitor, I also analyzed whether the combined percentage of looks to both the target and the competitor differs between positive and negative sentences. Previous studies (Fischler et al., 1983; Lüdtke et al., 2008) suggest that negation reduces the activation level of words under its scope. In our paradigm, this effect might shift participants' attention away from pictures of the negated concept all together, and towards the picture of the person and distractors. For example, we might expect less combined looks to the open *and* closed windows in negative sentences than positive sentences. However, this prediction is not borne out. By simply inspecting Table 34 we can see percentages of total looks to the target and competitor are similar among all conditions and across almost all regions. Repeated measure one-way ANOVA shows that the only region where there is a significant difference among conditions is the [SIL]&"his/her" region ($F_1(3,35) = 7.46$, $p_1 <0.01$; $F_2(3, 38) =4.12$, $p_2=0.008$). Paired-sampled t-tests in this region show that there is no difference between simple positive and negative: $t_1=-1.26$, $p_1=0.22$; $t_2=-0.28$, $p_2=0.78$, but there is a significant difference between cleft positive and negative: $t_1=-3.46$, $p_1=0.001$; $t_2=-2.52$, $p_2=0.02$. Note however this region is much shorter in cleft conditions (average 195ms) compared to simple conditions (average 355ms), due to a difference in the length of post-verb silence. Therefore we should not read too much into the difference

between cleft positive and negative in such a short region (the difference might be
due to random fluctuations).

	By subject			By item		
Simple	df	t1	p (2-tailed)	df	t2	p (2-tailed)
verb	35	-0.898	0.376	38	-0.749	0.459
SIL&his	35	3.203**	0.003	38	2.195*	0.034
someone's	35	4.518***	6.82E-05	38	2.995**	0.005
noun	35	3.256**	0.003	38	2.435*	0.020
Cleft						
verb	35	0.715	0.479	38	0.529	0.600
SIL&his	35	0.399	0.692	38	0.026	0.979
someone's	35	0.209	0.836	38	1.226	0.228
noun	35	3.223**	0.003	38	1.738	0.090

Table 35 paired sample t-tests on log ratio between positive and negative

Simple		By subject			By item		
		df	t_1	p (2-tailed)	df	t_2	p (2-tailed)
A	verb	35	0.277	0.783	38	0.218	0.829
	SIL & his	35	4.540***	6.381E-05	38	3.338**	0.002
	someone's	35	7.078***	3.028E-08	38	6.200***	3.03E-07
	noun	35	4.858***	2.47E-05	38	5.587***	2.10E-06
N	verb	35	1.617	0.115	38	1.368	0.179
	SIL & his	35	-0.180	0.858	38	-0.576	0.568
	someone's	35	0.919	0.364	38	1.875	0.068
	noun	35	3.153**	0.003	38	3.146**	0.003
Cleft							
A	verb	35	-0.166	0.869	38	0.143	0.887
	SIL & his	35	0.194	0.847	38	-0.504	0.610
	someone's	35	2.634*	0.012	38	2.492*	0.017
	noun	35	5.815***	1.35E-06	38	6.171***	3.316E-07
N	verb	35	-1.499	0.143	38	-0.674	0.505
	SIL & his	35	-0.368	0.715	38	-0.613	0.544
	someone's	35	3.034**	0.005	38	1.605	0.117
	noun	35	3.200**	0.003	38	3.158**	0.003

Table 36 one sample t-test comparing log ratios with zero on all conditions

5.4.3 Timecourse analysis

In order to determine when exactly a target bias was established, we conducted a time-course analysis on a one-second time period from the offset of the verb. We divided this period into ten 100ms time slices, and calculated a target/competitor natural log ratio for each condition. Figure 21 and Figure 22 plot the averaged log ratios for 10 time slices from the offset of verb, for simple sentences and cleft sentences respectively. They show that shortly after the verb (in the first 5 slices), log ratios differ greatly between simple positives and negative, but are almost identical between cleft positive and negative. Later on (from slice 6 onwards), log ratios of positive and negative differ in both the simple condition and the cleft condition. We performed an overall time (10) by clefting (2) by polarity (2) three-way ANOVA, and time (10) by polarity (2) ANOVAs for simple sentences and cleft sentences separately. Over 10 time slices, the time by clefting by polarity interaction is significant by participant: $F_1(9,315)= 2.8$, $p=0.04$, $\eta_p^2= 0.074$; $F_2(9,342)= 1.54$, $p= 0.20$, $\eta_p^2= 0.04$. Looking at simple and cleft sentences separately, for simple sentences there is a significant time by polarity interaction: $F_1(9,315)= 2.42$, $p= 0.036$, $\eta_p^2 = 0.45$; $F_2(9,342)=2.47$, $p=0.03$, $\eta_p^2= 0.43$. For cleft sentences, the time by polarity interaction is not significant (but trending by participants): $F_1(9,315)=2.22$, $p=0.053$, $\eta_p^2= 0.43$; $F_2(9,342)=1.09$ $p=0.4$, $\eta_p^2= 0.25$.

To determine the point at which a reliable target bias is formed, we performed one-sampled t-tests comparing log ratios with zero for each time slice (Table 37, reporting both the original p values and the Šidák corrected p values). Results show that for simple positive sentences, the target bias was significant from 200ms after the offset of the verb. For simple negatives, the target bias has trending significance

only in the 10th time slice (see Figure 21). For cleft sentences, the target bias becomes significant in the 6th time slice for cleft positives (trending in the 5th). For cleft negatives, the target bias is significant by subject in the 6th and 7th slices and significant by item in the 9th slice (see Figure 22). The results further demonstrate the difference in processing time between simple positive and negative, and the lack of difference in processing time between cleft positive and negative. Importantly, the target bias is formed earlier in cleft negatives than simple negatives, despite the fact that cleft negatives are structurally more complex.

Simple	100ms slice post verb	By subject				By item			
		df	t_1	p (2-tailed)	P (Šidák corrected)	df	t_2	p (2-tailed)	P (Šidák corrected)
A	1	35	1.10	0.28	1	38	0.75	0.46	1
	2	35	3.17*	3.1E-03	0.03	38	2.69	0.01	0.10
	3	35	5.81***	1.4E-06	1.3E-05	38	5.07***	1.0E-05	1.0E-04
	4	35	5.87***	1.1E-06	1.1E-05	38	5.26***	5.5E-06	5.3E-05
	5	35	5.63***	2.4E-06	2.3E-05	38	5.24***	5.8E-06	5.7E-05
	6	35	5.88***	1.1E-06	1.1E-05	38	5.04***	1.1E-05	1.1E-04
	7	35	5.69***	2.0E-06	1.9E-05	38	5.94***	6.8E-07	6.7E-06
	8	35	5.89***	1.1E-06	1.1E-05	38	6.07***	4.6E-07	4.5E-06
	9	35	5.33***	5.9E-06	5.8E-05	38	5.07***	1.1E-05	1.0E-04
	10	35	5.41***	4.6E-06	4.5E-05	38	5.38***	4.0E-06	3.9E-05
N	1	35	0.63	0.54	1	38	-0.13	0.90	1
	2	35	-0.58	0.57	1	38	-1.16	0.25	1
	3	35	-0.98	0.33	1	38	-0.95	0.35	1
	4	35	-0.72	0.47	1	38	-0.65	0.52	1
	5	35	0.33	0.74	1	38	0.49	0.62	1
	6	35	1.07	0.29	1	38	1.79	0.08	0.78
	7	35	1.03	0.31	1	38	2.04	0.05	0.49

		35	1.52	0.14	1	38	2.78	0.01	0.10
	8	35	1.52	0.14	1	38	2.78	0.01	0.10
	9	35	2.03	0.05	0.49	38	2.44	0.02	0.2
	10	35	2.65	0.01	0.10	38	2.85	0.007	0.07
Cleft									
A	1	35	-0.61	0.54	1	38	-0.75	0.46	1
	2	35	0.84	0.40	1	38	0.05	0.96	1
	3	35	1.10	0.28	1	38	0.73	0.47	1
	4	35	1.09	0.28	1	38	0.94	0.35	1
	5	35	2.87	0.007	0.07	38	2.80	8.00E-03	0.08
	6	35	4.07***	2.0E-04	0.002	38	3.48*	1.00E-03	0.01
	7	35	5.31***	6.2E-06	6.1E-05	38	4.33**	1.06E-04	0.001
	8	35	5.57***	2.9E-06	2.8E-05	38	5.15***	8.26E-06	8.1E-05
	9	35	6.17***	4.6E-07	4.5E-06	38	5.41***	3.7E-06	3.6E-05
	10	35	5.96***	8.8E-07	8.6E-06	38	4.86***	2.03E-05	2.0E-04
N	1	35	-0.30	0.77	1		-0.24	0.81	1
	2	35	-0.45	0.65	1	38	-1.07	0.29	1
	3	35	1.53	0.14	1	38	-0.04	0.97	1
	4	35	1.85	0.07	0.68	38	0.48	0.63	1
	5	35	2.43	0.02	0.2	38	1.43	0.16	1
	6	35	3.52**	1.2E-03	0.01	38	2.23	0.03	0.29
	7	35	3.81**	5.3E-04	0.005	38	2.08	0.04	0.39
	8	35	2.37	0.02	0.2	38	2.32	0.03	0.29
	9	35	2.41	0.02	0.2	38	3.25*	0.002	0.02
	10	35	1.29	0.21	1	38	2.62	0.01	0.098

Table 37 one sample t-test comparing log ratios with zero in 100ms time slices from the offset of verb

Post verb average log ratio in 100ms slices - Simple

Figure 21 Average target/competitor log ratios in 100 time slices from the offset of verb - Simple. As in Chapters 3 and 4, asterisks indicates that the value is significantly different from zero by both subject and item.
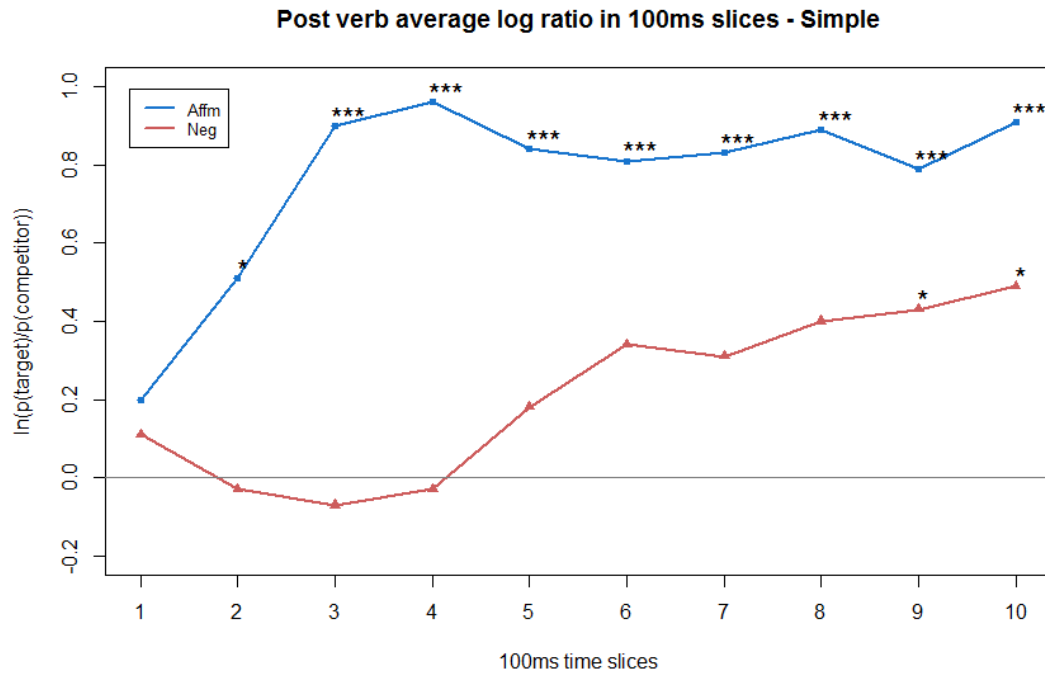

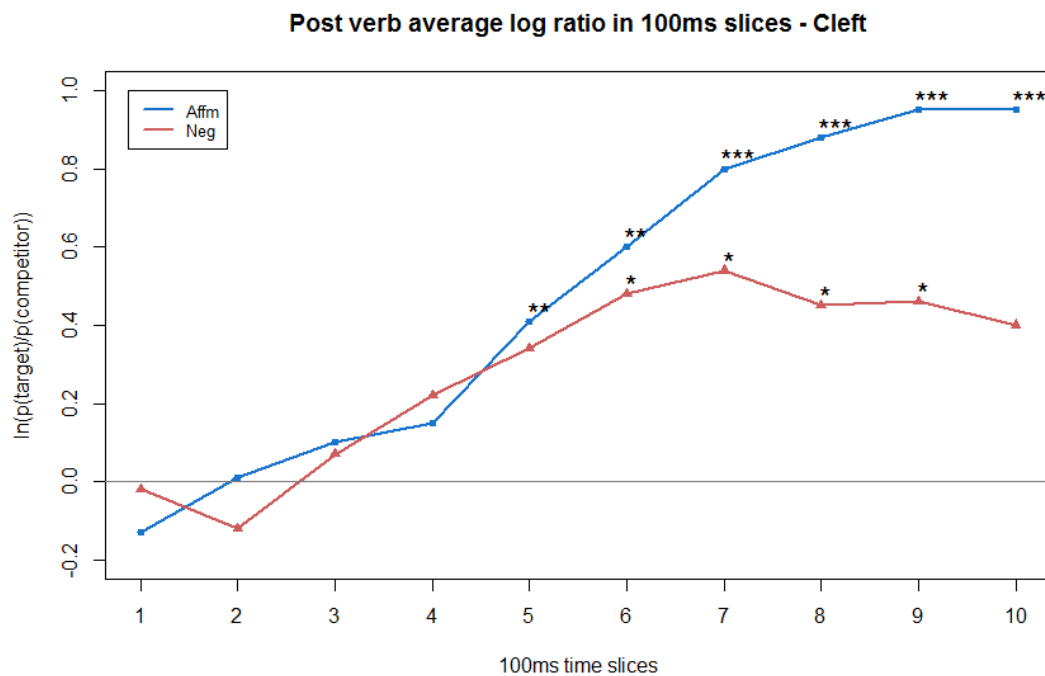**Post verb average log ratio in 100ms slices - Cleft**

Figure 22 Average target/competitor log ratios in 100 time slices from the offset of verb - Cleft. Asterisks indicates that the value is significantly different from zero by both subject and item.

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5.5 Discussion:

This study shows that for simple sentences, the processing of negatives is delayed compared to positives. Shortly after the verb in simple negative sentences like "Matt hasn't shut his dad's window", participants paid comparable attention to both the representation of the positive counterpart (a shut window) and the representation consistent with the negative sentence meaning (an open window). This suggests that when processing simple negative sentences, the positive counterpart is initially activated. However, around 900ms after the offset of the verb (in the noun region), participants shifted their attention away from the positive counterpart, and focus on negation-consistent representation. In comparison, when hearing a simple positive sentence like "Matt has shut his dad's window", participants shift their attention to the target representation (shut window) immediately after the verb.

In the case of cleft sentences, the processing of negatives is no more delayed than the processing of positives. When hearing either a positive or negative cleft sentence, participants pay comparable attention to both the target and the competitor representation after the verb. For cleft positives, a target bias became significant at around 500ms after the offset of the verb, and for cleft negatives, it took around 600ms. Participants' attention shifted away from the competitor and onto the target n "dad's" region (as in "*his dad's window*"), before the onset of noun. The time-course of the processing of cleft negatives is very similar to cleft positives. Sentences of both polarities experienced some delay, and this is likely due to the complexity of the cleft construction.

Comparing results from simple and cleft sentences, there is a difference between simple but not cleft sentences, as demonstrated by the significant polarity by

cleftness interaction in a post-verb window. What's more, a target bias is formed earlier in cleft negatives than simple negatives, despite the fact that cleft negatives are structurally more complex than simple negatives. These results suggest that the processing delay in simple negatives is not in fact caused by the first step of negation processing. Rather, it is likely due to QUD accommodation. Without context or further cues, the most prominent QUD for a simple negative sentence is whether the positive counterpart is true [27], e.g. *whether Matt has shut his dad's window*. Accommodating this QUD results in the representation of the positive counterpart. It also causes a delay in sentence processing, as the presentation of the positive counterpart is incongruent with the negation consistent presentation. In contrast, a cleft negative sentence has a negative prominent QUD, such as *who hasn't shut their dad's window*. The representation of this QUD is congruent with the representation of the sentence meaning. Similarly, a cleft positive sentence has a positive prominent QUD, such as *who has shut their dad's window,* which is also congruent with the representation of the sentence meaning. Therefore, the processing of a negative cleft sentence is no more delayed than the processing of a positive cleft sentence.

One might argue that our results in fact show that among simple positive, simple negative, cleft positive and cleft negative, only simple positive has a clear advantage in processing speed compared to the other three. Therefore, the slowdown in simple negative, cleft positive and cleft negative are all due to structural difficulty. Compared to our proposed explanation, this argument is weak. Remember that a

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[27] Note that in our stimuli, simple negative sentences have a stress on "hasn't". The accommodation of the positive QUDs is encouraged by the stress on "hasn't" but it does not rely on it. Tian et al. (2010) shows that when simple negative sentences are presented in written form, participants still accommodate positive QUDs. However, if there is a prosodic focus on other constituents of the sentence, the accommodated QUD may not be positive. For example, for "[MATT]$_f$ hasn't shut his dad's window", the prominent QUD is in fact negative (who hasn't shut their dad's window).

target advantage was formed *earlier* in cleft negatives than in cleft positives. Therefore, this argument requires the assumption that negation or clefting alone pushed the processing time to the ceiling. When negation and clefting are combined, the sentence is no more difficult to process than negation or clefting alone. Miller (1962) found that positive sentences take less time to process than simple negative sentences and simple passive sentences, both of which take less time to process than sentences that are both negative and passive. Based on this finding, it is unlikely that in our experiment, simple negatives, cleft positives and cleft negatives have all reached a ceiling processing time.

5.5.1 Evaluation of current results against rejection accounts

Our results are incompatible with rejection accounts in at least four predictions. First, according to rejection accounts, we should see that both simple and cleft negative sentences are delayed compared to their positive counterparts, given that both types of negative sentence express the same proposition. Instead, we saw that only simple negatives are delayed compared to their counterparts. Second, rejection accounts predict that the processing of cleft negatives is as delayed as, or more delayed than, simple negatives. Instead, attention to the target was formed earlier in cleft negatives than simple negatives. Third, rejection accounts should predict that when processing a negative sentence participants FIRST represent the positive counterpart and then represent the state of affairs consistent with sentence meaning. Instead, we saw that when hearing a simple negative sentence, participants paid comparable attention to both the representation of the positive counterpart and the negation consistent representation, before shifting attention away from the positive counterpart representation. This suggests that representation of the positive counterpart is not a

discrete first step, but happens in parallel with representing the sentence meaning.

Fourth, rejection accounts predict that the meaning of negation is incorporated after

the positive argument is processed. However, our results for cleft negatives suggest

that the meaning of negation can be incorporated incrementally. A target bias was

formed just 600ms after the offset of the verb, before the onset of noun. The time-

course is similar to cleft positives. This suggests that participants start combining the

meaning of negation with the verb as soon as they hear the verb, namely "not shut"

implies "open". This information is then used to infer the shape/state of the target

object, and direct their visual attention to the object that is compatible with the

combined meaning of the negation, the verb and the noun.

5.5.2 The representation of the positive counterpart

Coming back to the literature on the activation of the positive counterpart during

negative sentence processing, our results for simple negative sentences support

previous findings that the positive counterpart can be activated in the early stage of

negative sentence processing. The early occurrence of this representation supports

the idea that QUD accommodation happens incrementally during sentence

processing.

In terms of the duration of the activation of the positive counterpart, in our visual

world paradigm, it lasted for around 800ms - 900ms. This duration is compatible

with the findings of Hasson and Glucksberg (2006) as well as Kaup, Lüdtke, &

Zwaan (2006). Note that in our visual world paradigm, all potential representations

are present on the screen from one second before the sentence starts. Therefore, the

effort of constructing a visual representation consistent with either the positive

counterpart or the negative sentence is reduced compared to the visual probe recognition paradigm of Tettamanti et al., (2008) or Tomasino et al., (2010). Thus it is conceivable that outside a visual world paradigm, the positive counterpart stays active for longer when participants process simple negative sentences out of context.

Our results also show that the activation of the positive counterpart is not a discrete first step, but happens in parallel with the activation of sentence-meaning consistent representation. The results from most other studies have no support for this. They generally found higher accessibility of the positive counterpart than the negation-consistent representation during the early stages. How can we reconcile our results with these findings? Once again, in our paradigm all potential representations are visually present on the screen. Without such visual stimuli, it is highly likely that representing the state of affairs consistent with the negative sentence takes longer than representing the positive counterpart, as the former involves an extra inferential step. For example, to form a representation based on the stimulus, 'the window is not open', participants must infer that the window is closed and represent such a state, whereas to form a representation for, 'the window is open', no additional inference is required beyond access to the meanings of the predicates. Thus, in paradigms where representations are not shown in advance, participants may first arrive at the representation of the QUD since the positive counterpart is easier to access. Overall our data in simple sentences support previous findings that the positive counterpart can be activated during negation processing.

However, we also found that when a negative sentence has a negative QUD (as in the cleft case), participants do not first represent the positive counterpart. Although participants looked at both the target and the competitor for 400ms-500ms after the verb, this does not necessarily mean that it was caused by the representation of the

positive counterpart. For cleft positive sentences, participants also looked at the competitor for a similar period. For example, when hearing "It is Matt who has shut his dad's window", participants were looking at both a shut window and an open window after the offset of "shut". There is no reason to represent the negative counterpart when processing a positive sentence. One might argue that the positive cleft sentence has a negative implicature, such as "other people haven't shut their dad's window", and participants were representing the negative implicature immediately after the verb. Although research on implicature processing shows that implicatures (especially scalar implicatures) can be accessed incrementally with little or no delay compared to accessing the semantic meaning of the sentence, especially when there is supporting context, the representation of implicatures should be long lasting (Hasson & Glucksberg, 2006; Kaup & Zwaan, 2003; W. H. Levine & Hagaman, 2008; MacDonald & Just, 1989). Therefore, it is unlikely that such an early and short activation is due to the representation of implicatures. A likely explanation for the short competitor interference is that hearing the verb (shut) and predicting the form of the noun (window) caused bottom-up lexical activation of the representations of "shut" and "window" (see Barr, 2008). Overriding the bottom-up activation is slower in cleft sentences than simple sentences, due to the extra cognitive effort required for processing the cleft construction.

5.5.3   Unpredicted results

What was slightly surprising was that after a target bias was formed in negative sentences, it was still smaller compared to positive sentences (although in the case of clefts, the difference is significant by subject only). In the graphs, this corresponds to the red lines staying below the blue lines in the later stages of the sentence. This

could be due to the pragmatic inferences of negative sentences. When hearing "Matt hasn't shut his dad's window", it is plausible that shutting the window is a desirable event or a likely future event. Therefore participants might look at the likely future state of the noun. In our pilot study, I tested sentences in future tense, such as "Matt will shut his dad's window". Although the sentence indicates that currently the window is open, participants never establish a target bias. Instead, they continue looking at both the open and the shut window throughout.

In addition, I predicted that if negation reduces the activation level of words in its scope, we should see less attention to pictures of the negated word (e.g. windows, whether open or closed) in negative sentences compared to positive sentences. However this prediction is not borne out. Studies (MacDonald & Just, 1989 experiment 3; Levine & Hagaman, 2008) suggest that negation reduces the accessibility of the linguistic form rather than the concept of words in its scope. If this is the case, it could be that attention to pictures that correspond to the negated word is affected by the level of representation of concepts more than the linguistic form.

5.5.4   Implications

Beyond the processing of negation, this study relates to the broader question of how pragmatic information is incrementally updated during sentence processing. Research has grown in the online integration of pragmatic information. For example, we can integrate common ground and speaker's epistemic state at the earliest moment and use such information to predict upcoming referents (Breheny, Ferguson, & Katsos, 2013; Heller, Grodner, & Tanenhaus, 2008); we can access scalar

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implicatures on-line with little or no delay (Breheny et al., 2012; Grodner et al., 2010); we infer information about the speaker using accents and cultural heuristics, and use it to anticipate upcoming words in a sentence (Van Berkum, van den Brink, Tesink, Kos, & Hagoort, 2008). However, as far as I know, there have been no prior studies in the online accommodation of QUD. I have shown that the linguistic form of a sentence contains cues for how it is related to the prior context. On hearing or reading a sentence when there is insufficient or no context, comprehenders do not just process the semantic meaning of a sentence, rather, they also use cues to infer and accommodate a likely context, specifically a QUD. This process is automatic and incremental. Negation is one such cue for retrieving a prominent QUD. Without other cues (such as cleft construction), the most prominent QUD for a negative sentence is positive. This is why studies often report the representation of the positive counterpart in negation processing.

5.6   Conclusions

I investigated why participants represent the positive counterpart when processing a negative sentence, and when such representation takes place. The study shows that the representation of the positive counterpart is not a mandatory first step of negation processing. Instead, it happens when a contextless negative sentence triggers the accommodation of a positive QUD. When a negative sentence has a negative prominent QUD, participants no longer represent the positive counterpart. Results from eye movements reveal that QUD accommodation happens soon after negation is encountered, and the meaning of negation can be incrementally incorporated.

Overall, this finding adds to the growing literature that the processing of pragmatic information does not happen only at constituent or clausal level, rather it can be processed and integrated incrementally.

Chapter 6   General Discussions and Future Research

Over the course of the past five chapters I have investigated the processing of negative assertions: utterances that express negative propositions. In this chapter, I first summarize and discuss the main ideas and findings as they unfold in each chapter. I then discuss the methodological and theoretical implications of this thesis. Lastly, I present a few ideas for future research.

6.1   Summary and discussion of main findings

I started this inquiry with questions drawn from psycholinguistic research on the effect of negation on sentence processing and from linguistic research in the pragmatic functions of negative assertions.

Numerous psycholinguistic studies have shown that negative sentences are more costly to process than their positive counterparts, even though negation is used frequently in natural settings. The extra cost manifests in longer reading times, longer response times in sentence verification tasks, higher error rates, worse memory of the content in negative sentences, worse performance in logical reasoning when negation is involved, and the late acquisition of denial by children. In addition, studies show that in the early stages of processing negative sentence, their positive counterparts are often, but not always represented. However, when there is contextual support, both effects - the extra cost of negation and the representation of the positive counterpart- are reduced or eliminated. These findings beg for a theory of negative sentence processing that can explain all these effects, and gave rise to the first questions I posed herein:

Question 1a: why are negative sentences difficult to process (at least in psycholinguistic experiments)?

Question 1b: why is the representation of the positive counterpart often involved?

Pragmatic research has shown (Horn, 1989) that negative sentences have richer pragmatic effects than positive sentences. For example, doubly negated sentences convey different meanings from the positive alternatives. Out of context, negative sentences are often less felicitous than positive sentences with roughly same semantic content. Also, negation allows us to infer contextual information. Consider this example, I came across a talk on the internet titled "30 is not the new 20". When I saw this title, I thought to myself, I didn't know that people are currently debating whether 30 IS the new 20. This is inferred because the title was negative. In comparison, if the title was "30 is the new 20". I couldn't have inferred such background information. This pragmatic effect lead to my second question:

Question 2: how does negation allow us to infer background contextual information?

In Chapter 1, I surveyed psychological findings and reviewed current theories against these findings. Current theories of negation processing come from three perspectives: grammatical, rejection-based or contextual. Grammatical accounts propose that negative sentences are harder to process because they are syntactically more complex than positives. This approach only addresses the extra processing cost of negation, and does not explain the other effects. Rejection accounts flow from the idea that negation functions as a truth-functional operator: it reverses the truth value of the embedded positive proposition. Based on this function, rejection accounts propose that a negative sentence is represented as the rejection of its positive argument,

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where the positive argument is always processed and represented first. Rejection accounts explain the extra cost of negation in terms of the extra step of embedding. They also account for the early representation of the positive counterpart, as it is the first step of negation processing. However, this account cannot explain why the representation of the positive counterpart does not always occur. In addition, it implies that the meaning of negation is not incorporated until the positive argument is processed, which is at odds with the prevalent findings of incremental sentence processing. The contextual approach suggests that with the right kind of contextual support, negative sentences are not difficult to process and the positive counterpart need not be represented. This account remains silent when it comes to why the positive counterpart IS often represented when there is no contextual support. Overall, current theories of negation processing are unsatisfactory in the face of the psycholinguistic findings.

To address the shortfalls of current theories, I proposed an alternative theory in Chapter 2: the dynamic pragmatic account. Starting from the observations from the contextual approach, it seemed clear that there are differences in how negative sentences interact with context compared to positive sentences. It is possible that the processing effects have a pragmatic cause, even though in the majority of the psycholinguistic studies, no context was explicitly provided. To explore how sentence processing interacts with context, I turned to the dynamic semantic/ pragmatic approach to meaning, which focuses on the interactive nature of language use. In this approach, utterance meaning goes beyond its linguistically coded content, and contains information about how the current utterance fits in the dynamically changing context: how it relates to prior discourse and how it constrains the

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upcoming discourse. Different types of utterances have different effects on context. Questions set up the goals of a conversation while assertions pay off these goals. When we interpret an assertion, we not only update the context with its asserted content, but also with pragmatically retrieved content, such as the presuppositions and the source of relevance for this assertion, described in terms of the Question Under Discussion the assertion pays off. If the presuppositions and QUD are not part of the context, comprehenders may be able to use presupposition triggers and QUD cues to retrieve and accommodate these elements. I argued that negation is a cue for retrieving a prominent positive QUD. Without other cues, the most prominent QUD for a negative sentence $\neg p$ is *whether p*. The projection of this positive QUD is due to the most frequent uses of negation (rejection and denial), and it is sensitive to other factors (e.g. frequency of the predicate and context) and other QUD cues (e.g. prosodic focus and cleft construction). Processing a negative sentence without context triggers the accommodation of a positive QUD, which happens automatically and incrementally. QUD accommodation contributes to the extra processing cost associated with negation; it explains why the positive counterpart is often represented; it also explains why contextual support reduces or eliminates both the extra cost and the positive representation.

In Chapters 3 – 5, I tested the dynamic pragmatic account against current theories (especially rejection accounts) in three series of experiments. Chapter 3 used a probe recognition paradigm to study the representations formed after reading negative sentences. The results show that shortly after reading a simple negative sentence, e.g. "John hasn't ironed his shirt", participants responded faster to a picture representing the positive counterpart (ironed shirt); on the contrary, after reading a cleft negative

sentence ("It is John who hasn't ironed his shirt".) or a negative question ("who hasn't ironed their shirt?"), participants responded faster to a picture that is consistent with the negative sentence meaning (crumpled shirt). This result argues against rejection accounts: the representation of the positive counterpart is not a mandatory first step of negation processing. Rather, it is likely due to QUD accommodation. While simple negative sentences project positive QUDs, cleft negative sentences project negative QUDs, which is why simple and cleft conditions generated different results in the probe recognition task.

Chapter 4 investigated the verification of negative sentences against pictures. Previous studies reported inconsistent reaction time patterns for true and false negatives: many found that TN is slower to verify than FN, some found that verifying TN and FN take roughly the same amount of time, and others found that TN is faster than FN. I reviewed three models of negative sentence verification: rejection, conversion and predicate dependent. To explain the pattern TN > FN, rejection accounts propose that participants first verify the positive argument of negative sentences and then switch the truth index. Thus the truth effect in reaction times of affirmative sentences should be reversed in negative sentences: as TA is faster than FA, TN should be slower than FN. The conversion model explains the pattern TN < FN. It proposes that negative sentences are converted and represented in a positive format whenever possible. True sentences, whether they are affirmative or negative, should be faster to verify than false sentences. On the other hand, the predicate dependence model proposes that negative sentences with binary predicates are represented as a positive argument embedded under a negative operator, and those with unary predicates are converted and represented as positive sentences.

Thus, TN > FN is expected with binary predicates, while TN < FN is expected with unary predicates. None of the three accounts can explain the varying findings in sentence-picture verification studies. I proposed that two strategies- the default strategy and the truth functional strategy - can be used when verifying negative sentences against pictures; the development of the truth-functional strategy is triggered by the accommodation of positive QUDs. The default strategy is to infer the situation that makes the sentence true, and compare this situation with the evidence. Under this strategy, true sentences, regardless of their polarity, should be faster to verify than false sentences. However, the accommodated positive QUD is in conflict with the negative question posed by the task. The conflict may encourage participants to develop the truth functional strategy, where they no longer infer the truth condition of the negative sentence, but instead answer the positive accommodated QUD and then flip the truth index. My proposal was tested in experiments where participants verify negative sentences against pictures of one or two objects. For example, the sentence "the banana isn't peeled" against a picture of a peeled banana (one-object) or a picture of a peeled banana and a whole orange (two-object). The different picture contexts were set up to manipulate the polarity of the prominent QUD. With one-object pictures, the prominent QUD is positive (whether the banana is peeled); with two-object pictures, the prominent QUD should be negative (which one isn't peeled). Results show that (1) with pictures of one object, TN was faster than FN in the first early phase of the experiment, however their difference diminished in late phase; (2) with pictures of two objects, TN was faster than FN throughout the experiment. Finding (1) suggests that the proposed default strategy is indeed the default. The truth functional strategy, on the other hand, is developed specifically for the task after some training. Finding (2) suggests that it

is the accommodation of a positive QUD that encourages the truth conditional strategy. When the prominent QUD is negative, participants tended to use the default strategy throughout the experiment.

Chapter 5 studied the time course of negative sentence processing using a visual world eye-tracking paradigm. Participants listened to positive and negative sentences in simple and cleft forms, such as "(It is) Matt (who) hasn't shut his dad's window", while looking at a visual scene which contained images that matched or mismatched the sentence meaning (an open window and a closed window). Results showed that for simple sentences, the processing of negative sentences was delayed compared to the processing of the positive sentences, due to the activation of the positive counterpart. In comparison, the processing of cleft negative sentences was no more delayed than the cleft positives. It confirms the findings from Chapters 3 and 4 that simple but not cleft negative sentences trigger the accommodation of positive QUDs. Importantly, this study showed that both QUD accommodation and the integration of the meaning of negation can happen incrementally. In the simple negative condition, attention to the picture representing the positive counterpart arose immediately after the verb was encountered and dropped before the end of the sentence, which echoes previous findings that the representation of the positive counterpart is early and temporary. This suggests that the QUD accommodation happens in the early stage of sentence processing. In both the simple and the cleft negative conditions, the meaning of negation was incorporated before the end of the sentence (though considerably earlier in the cleft condition), suggesting that the integration of the negation need not wait until after the positive argument is processed.

Based on the findings of these experiments, we can now answer the two sets of questions posed in the introduction. According to the dynamic pragmatic account, Questions 1a, 1b and 2 are all connected by positive QUD accommodation. Without other cues or supporting context, a negative sentence ¬p projects the prominent positive QUD *whether p*. The accommodation this QUD contributes to the processing cost and explains why the positive counterpart of negation is often represented. We can infer background contextual information from a negative sentence because we assume that the positive QUD is relevant. In the example of, "30 is not the new 20" or the example from the introduction, "This is not a hotel", we assume that the positive QUDs *whether 30 is the new 20* and *whether the venue is a hotel* are relevant, and infer prior discourse context or prior events that make these questions relevant.

6.2 Methodological implications and theoretical implications

This thesis has methodological and theoretical implications for future research. Methodologically, when we study sentence processing using psycholinguistic experiments, we must not overlook the pragmatic effects associated with these sentences. Commonly, psycholinguistics research studies the effect discourse context has on language processing by explicitly providing discourse contexts. If no context is provided, contextual effects are often ignored. I have shown in three series of experiments that when sentences are presented *without* context, participants automatically retrieve and accommodate relevant contextual information such as QUD. Sentence comprehension is NEVER independent from contextual effects. This finding suggests that when we design psycholinguistic experiments and interpret

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their results, we must consider the likely pragmatic processes, and how they interact with the processing of the sentences' linguistically coded meaning.

Theoretically, the finding that QUD accommodation happens incrementally relates to the broader question of how pragmatic information is incrementally updated during sentence processing. There is growing research in the online integration of pragmatic information, such as the speaker's epistemic state (Breheny et al., 2013; Heller et al., 2008) and scalar implicatures (Breheny et al., 2012; Grodner et al., 2010). However, as far as I know, there has been no prior psycholinguistic study of QUD accommodation. I have argued that while QUD accommodation shares similar properties with presupposition accommodation, they are distinct processes. In the dynamic semantic/ pragmatic approach to meaning, many scholars (Carlson, 1983; Ginzburg, 2012; Kehler, 2012; Lewis, 1979; Roberts, 2012) have argued for the importance of QUD in discourse structure and coherence. This research provides the first piece of psycholinguistic evidence for the retrieval and accommodation of QUD during sentence processing, and gives preliminary indications of the time frame of QUD accommodation. Research in this thesis can serve as a precursor to the psycholinguistic study of QUD accommodation during language comprehension.

6.3   Future research

The studies in this thesis have answered some questions while raising more. Questions that immediately come to mind are: how can the dynamic pragmatic account be adapted to account for effects of implicit negation, embedded negation and negative quantifiers? How can we explain pragmatic effects in negative polar questions? More generally, how are questions represented cognitively? How do we mentally represent different elements in context? In this section, I discuss just three ideas in more detail.

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6.3.1 Unaddressed finding: reduced accessibility of negated words

My research questions did not address all the findings reviewed in Chapter 1. One finding concerned the accessibility of negated words: some studies (e.g. Levine & Hagaman, 2008; MacDonald & Just, 1989) found that the accessibility of a word is reduced when it is negated compared to when it is affirmed. MacDonald and Just (1989) found that after reading sentences such as "Almost every weekend, Elizabeth bakes cookies but no bread for the children", the word "cookies" is more activated than "bread", but words that are semantically related to "cookies" are not more activated than words related to "bread". MacDonald and Just concluded that negation reduces the accessibility of the linguistic form of words in its scope, but this effect may not spread to associates of negated words. Their proposed explanation was that negated concepts are less likely to be the topic for upcoming discourse than affirmed concepts, and as a result, attention is shifted away from negated concepts. This proposal implies that if the negated concept is marked as the discourse topic (e.g. cleft construction, prosodic focus), its negated words should be equally, or nearly equally, as accessible as affirmed words.

I tested this hypothesis in a pilot study where I compared the accessibility of negated words marked as discourse topics versus those not marked as topics. According to the discourse focus shift hypothesis proposed by MacDonald and Just (1989), negated words should only be less accessible than affirmed words when they are not discourse topics. The pilot study was done in Chinese. Chinese is a topic-prominent language that commonly uses fronting to mark discourse topics (Li & Thompson, 1976). For example: sentence (40a) follows the predominant SVO word order (see 40c). In this sentence, the object "Zhangsan" is not the topic unless it is prosodically

focused. However, if we want to linguistically mark that the object (Zhang-San) is the topic, we can move it to the front of the sentences seen in (41b), resulting in an OSV word order.

40a)		我　已经　见过　了　张三。
40b)	Transcription:	wo yijing jianguo le Zhangsan.
40c)	Gloss:	I already see-EXP RES Zhang-San
41a)	English translation: I have already seen Zhang-San.	
41b)		张三　　我　已经　见过　了。
41c)	Transcription:	Zhangsan wo yijing jianguo le.
41d)	Gloss:	Zhang-San I already see-EXP RES

1a) English translation: (As for) Zhang-San I have seen him already.

My pilot study used a word probe recognition paradigm similar to MacDonald & Just (1989). Participants read short passages containing an introduction, a main sentence (containing the target noun) and a short coda (see Table 38). The introduction and coda are the same for all conditions. The main sentence contains the target noun (underlined in the examples) which is either fronted (thus becoming the discourse topic) or not. The experiment thus has a 2 (positive/ negative) by 2 (normal order/ fronted) design. The target noun is the grammatical object of the sentence. In the fronted condition, the target noun linearly precedes negation. Participants read the passages section by section (marked with slashes). After the sentence, a probe word appeared and participants answered whether the word appeared in the sentence. In the experimental condition, the probe word was always the target noun.

According to the discourse focus shift hypothesis (following McDonald and Just), we should see that after reading sentences in normal order, responses to the target words are slower when it is negated than when it is affirmed. However, after reading sentences in fronted order, response times to the target should be the same when it is negated versus when it is affirmed. Thus, we predict a word order by polarity interaction in RT.

Thirty-six native Mandarin speakers read 32 experimental sentences and 48 fillers, word order (normal/ fronted), sentence polarity (positive/ negative) and answer polarity (yes/no) were all counterbalanced.

The average reaction times per condition are charted in Figure 23. Contrary to the prediction, we saw that RT in the negative condition is shorter than in the positive condition in both word orders. This is confirmed by a 2(word order) by 2(polarity) ANOVA which showed no significant interaction between word order and polarity (Fs<0.28). Instead, there was a main effect of polarity, i.e. whether the word order was normal or reversed, responses to probe words in negative sentences were slower than affirmative sentences $F_1(1,35)=12.18$, $p_1=0.001$; $F_2(1, 31)=5.98$, $p_2=0.02$. There was also a trending main effect of word order (significant by participants only). RT in the normal order condition was shorter than RT in the reversed order condition: $F_2(1,36)=4.89$, $p_1=0.033$; $F_2(1,31)=1.84$, $p_2=0.185$. This effect can be explained by the shorter distance between the target word and the probe word in the normal order condition compared to the fronted condition.

The result of this pilot study is inconsistent with the prediction of the discourse focus shift hypothesis. Even when the target noun is marked as discourse topic, its

accessibility is still reduced when it is negated rather than when it is affirmed. This suggests that it is not an attention shift in discourse representation that caused the reduced accessibility effect. A possible explanation is that negation can lead to a "shallower" relational integration of the semantic features of words under its scope compared to words that are affirmed. . Consider the sentence "I closed the door". To represent the situation corresponding to this sentence, we must integrate "close" and "door" using our encyclopedic knowledge and generate a mental representation of a closed door. It is possible that with supportive context, when hearing "I didn't close the door", the negation amends the way "close" and "door" are normally combined, and the focus is on inferring what the situation is like when the door is not closed. This idea is in need of further research.

One potential paradigm is a memory recall task. Cornish and Wason (1970) found that people remember positive sentences more accurately than negative ones. We can test whether participants have more difficulty remembering *which* words appeared under the scope of negation, or remembering the *combination* of those words. For example, after reading the sentences "John didn't buy any pears" and "John didn't cook any apples", whether participants have more difficulty remembering that the words "buy", "cook", "apples" and "pears" appeared under negation, or that they find it more difficulty remembering that "buy pears" appeared rather than "cook pears" (and likewise "cook apples" appeared, rather than "buy apples"). Another potential direction is an fMRI study comparing levels of activation in the prefrontal cortex when processing positive and negative sentences, where the predicates require more encyclopaedic feature integration in the positive condition than in the negative condition. This difference can be achieved by pretesting the complexity of events

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corresponding to the positive versus the negative sentence. Previous studies (Hindy et al., 2013) found that when participates look at pictures depicting an object before and after an event simultaneously (e.g. a coned ice-cream when it is frozen and when it has melted), the prefrontal cortex is active. This is the area that is known to be responsive to conflict and visual inhibitory control (e.g. in a Stroop task). The current hypothesis should predict that the prefrontal cortex is more active when reading positive sentences than negative sentences.

Intro	小红/	有	个/	特点,/				
(Transcription)	Xiaohong/	you	ge/	tedian,/				
(English)	Xiaohong/	has	a/	trait,/				

Main sentence	Normal order				Fronted order			
Negative	她/	不	吃/	草莓,/	草莓/	她/	不	吃,/
(Transcription)	ta/	bu	chi/	caomei,/	caomei/	ta/	bu	chi,/
(English)	she/	doesn't	eat/	strawberry,/	(as for) strawberry/	she/	doesn't	eat (it),/
Positive	她/	爱	吃/	草莓,/	草莓/	她/	爱	吃,/
(Transcription)	ta/	ai/	chi/	caomei,/	caomei/	ta/	ai/	chi,/
	she/	likes (to)	eat/	strawberry,/	(as for) strawberry/	she/	likes (to)	eat (it),/

Coda	一向	如此。 /						
(Transcription)	yixiang	ruci./						
(English)	always	so./						

Table 38 Examples sentences for pilot study on the accessibility of negated words
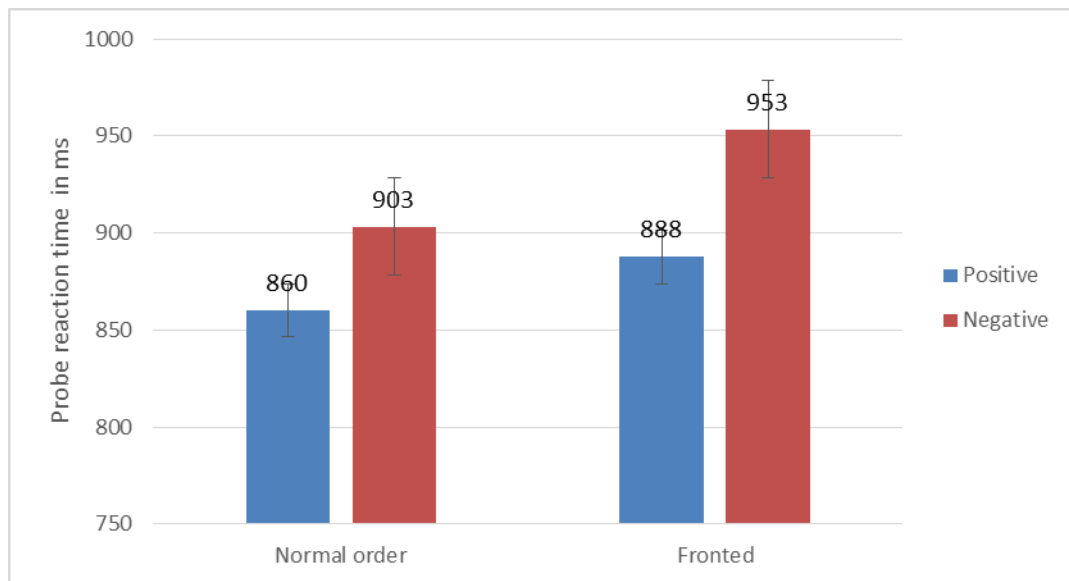
Figure 23 Reaction Times per condition: accessibility pilot study

6.3.2 Heim's context change potential of negation

As mentioned in Chapter 2, some dynamic semanticists (e.g. Kamp and Heim) propose that the meaning of a sentence is its context change potential. Heim (1992) gave an account of the context change potential for negation (illustrated in (2), where "+" means context update, and "\" means set-theoretic complementation): which states that the context change for an assertion with negation involves two steps: you first temporarily update the context set with the material under the scope of negation (i.e. the positive argument), and then subtract the resulting context. For example: the sentence "it is not raining "first updates the context with "it is raining", i.e. subsetting the current context by selecting only the worlds in which it is raining. Then the resulting context is subtracted from the original context, returning all the worlds in which it is not raining. This proposal follows the idea that all embedding atomic clauses within a complex sentence can update the context. The context change potential of a complex sentence is compositionally determined by the context

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change potentials of its constituents (Irene Heim, 1992). A negative sentence $\neg p$ is composed of the truth functional connective $\neg$ and an atomic positive proposition p. Thus, p is allowed to update the context.

2) $C + \text{not } \varphi = C \setminus (C+\varphi)$

This account was proposed to account for presupposition projection in negative sentences. It has been observed that when a presupposition trigger is fembedded under the scope of negation (which is seen as an entailment-cancelling operator), the presupposition survives (e.g. Stalnaker, 1973). For example, "the King of France is bald" presupposes and entails that there exist a unique King of France". The negative sentence "the King of France is not bald" also presupposes the existence of a unique King of France, even though the noun phrase is under the semantic scope of negation. Heim suggested that her account of the context change potential of negation can explain presupposition projection in negation. It works by assuming that the updates of context $c+\varphi$ is only defined when all the presuppositions of φ have updated the context. For "my cat isn't sick", first the context is updated by "my cat is sick". In order for that happen, the context must entail that the speaker has a cat. So first the context is updated by narrowing down to worlds in which the speaker has a cat, then it is updated by "my cat is sick", namely, narrowed down to worlds in which the speaker's cat is sick. This context is then subtracted, not from the *original* context, but from the context immediately before the update of "my cat is sick", after the update of "the speaker has a cat".

What does it mean to update the context in two steps? Von Fintel (2008) interpreted it as a "procedural". He said

> [it is] an instruction for what procedures need to occur in sequence […]. Rather than computing a context change potential for the complex sentence and applying it to the input context, what needs to be happening is to compute a context change potential for the simple embedded sentence, apply that to the input context, let accommodation occur to make that even possible, and then the resulting context is subtracted from the input context. This is a procedural semantics, not a "declarative one" (von Fintel, 2008: 156).

Heim's context change potential for negation might remind us of the rejection accounts of negation processing, however it is important to point out that neither Heim's original proposal nor von Fintel's interpretation of it are meant as a cognitive model, but only a conceptual theory. Therefore, the two steps of context updates need not be reflected in two mental representations. However, we should also allow the theoretical possibility that a two-step context updates *do* generate two mental representations. In that case, there is tension between Heim's account and the dynamic pragmatic account, as the former predicts that the positive counterpart of negation is mandatorily represented while the latter doesn't. To release this tension, we can assume that context updates do not necessarily lead to mental representation with perceptual properties, or I must provide another solution for presupposition projection in negative sentences.

My findings suggest that contextual updates *can* generate mental representations with perceptual properties. However, whether such representations *must* be generated for contextual updates remain a question for future research. If we take a leap and assume that the answer is yes, can we account for presupposition projection in

negation? An immediate thought is maybe the accommodated positive QUD can preserve the presuppositions seen in negative sentences. However, this is unlikely to be the answer, as the form and polarity of the prominent QUD for a negative sentence is influenced by many factors such as other QUD cues and context. For example, the sentence "[THE KING OF FRANCE]$_f$ is not bald" with a prosodic focus on "the king of France" projects a negative QUD *who is not bald.* In this case, the accommodated QUD does not preserve the presupposition that there exist a unique King of France.

One way out is to drop the assumption that presuppositions are "preserved" in negative sentences. Carston (1998) proposed that the semantics of negation is not presupposition preserving. Rather, presuppositions in negative sentences are pragmatically derived (see also Sperber & Wilson, 1986). With the previous example of "the King of France is not bald", Carston proposed that the the semantic content of this sentence is (42), which does not presupposes the existence of the King of France. However, this meaning is too weak and must be enriched to meet the criterion for optimal relevance (Sperber & Wilson, 1986). By default, they narrow the scope of negation which lead to (43), which entails the existence of the King of France. However, if after uttering "the King of France is not bald", the speaker added "because there is no King of France". This follow-up utterance and (43) lead to a contradiction: there is a King of France and there is no King of France. The contradiction triggers the hearer to abandon (43) and resort to (44): the echoic (metalinguistic) interpretation. (44) "returns" negation to its original wide-scope and cancels the presupposition. This account is appealing, but further assumptions may be required to account for presuppositions associated with triggers under the narrow

scope of negation. For example, "the King of France hasn't met my cat". Here it can be argued that the relevance requirement of the noun phrase "my cat" itself generates the implicature that the speaker has a cat. In any case, a pragmatic account of presupposition projection in negation is a possible solution which can spare the two step contextual updates account of negation.

42) Not [the King of France is bald].

43) [The King of France is not-bald].

44) Not ["the King of France is bald"].

6.3.3 Positive and negative polar questions

As mentioned briefly in Chapter 2, according to the dynamic pragmatic account, a simple negative sentence gives rise to an inferred *positive* QUD in the absence of other relevant information in the utterance situation. An important assumption I have made in this thesis is that positive and negative polar questions have different semantic contents. This assumption should be studied in future research, which in turn will shed light on competing semantic theories on questions. Mentioned in Chapter 2, repeated here, semantic theories of questions fall into at least two broad categories: the partition view and the proposition-abstraction view. Partition views propose that a question denotes the set of possible answers or exhaustive answers (Groenendijk & Stokhof, 1984; Hamblin, 1973). In this view, positive and negative polar questions are semantically identical, i.e. the question *whether p* and *whether ¬p* both denote $\{p, \neg p\}$. On the other hand, propositional abstraction views (Ginzburg & Sag, 2000; Hausser, 1983) suggest that a question denotes an abstract of its answers. For example, the question "who solved the problem" denotes the function f(x) such

that x solves the problem. By these views, positive and negative polar questions have distinct semantic denotations, as they are each abstracts of positive and negative propositions, i.e. *whether p* is an abstract over *p*, while the negative polar question *whether ¬p* is an abstract over *¬p*.

I propose that we can test these two competing views by comparing the cost of answering polar questions versus alternative questions (*p or not p*, e.g. "is the door open or not?"). Under the proposition abstraction view but not the partition view, polar questions and alternative questions have *distinct* semantic contents. We can test this using a paradigm similar to sentence-picture verification, presented in Chapter 4. Participants read polar or alternative questions followed by pictures that lead to a "yes" or "no" answer. Note that we cannot use English as alternative questions such as "is the door open or not" do not allow yes/no answers. Instead, we can use the "shi-bu-shi" (yes-not-yes) construction in Chinese, which is a common form of question that takes yes/no answers while explicating mentioning both *p* and *not p* (see (45a) as an example). The proposition abstraction view should predict that answer "no" to a polar question is more costly than to an alternative question. On the other hand, the partition view should predict no difference between answering "no" to polar versus alternative questions.

45a)　　　- 门　　是　不是　　开着？- 是. /不是.

45b)　　　- Door　yes　not yes　open? - Yes (meaning the door is open). /No (meaning the door is closed).

6.4   Summary

To summarize, this thesis set out to investigate why out-of-context negative sentences are difficult to process, why the positive counterpart is often represented, and why negative sentences allow us to infer richer contextual information than positive sentences. I proposed that negation is a cue for a prominent positive QUD. The accommodation of such QUDs can give satisfactory answers to all three questions. Three series of studies supported this account. The findings have radical implications for the interpretations of results from sentence processing studies, as well as opening new doors for the research in how pragmatic information is incrementally updated during comprehension. Future research is required to expand the dynamic account to account for a broader range of negation related effects.

Conclusions

This thesis studies how negative assertions are processed. Out of context negative sentences are more difficult to process than positives, and their positive counterparts are often represented in the early stage of processing. With contextual support, these effects diminish or disappear. In addition, negative utterances often lead hearers to infer richer background information than positive utterances. To account for both the processing effects and the pragmatic functions, I proposed the dynamic pragmatic account of negation processing. Under the dynamic pragmatic approach to meaning, utterance meaning goes beyond its linguistically coded content, and contains information about how a given utterance relates to the broader discourse. Specifically, when a hearer interprets an assertion, she will not only access the asserted content, but also the Question Under Discussion (QUD) addressed by this assertion, which can be retrieved using linguistic and nonlinguistic cues. Negation is a cue for retrieving a prominent QUD. Without contextual support or further cues, the most prominent QUD for a negative sentence $\neg p$ is the positive question *whether p.* The projection of this positive QUD is due to the most frequent uses of negation, rejection and denial, and is sensitive to other factors (e.g. frequency of the predicate and context) and other QUD cues (e.g. prosodic focus and cleft construction).

In three series of experiments, I have shown that without context, processing simple negative sentences (e.g. "John hasn't ironed his shirt") leads to the representation of states of affairs consistent with the positive counterpart ("John has ironed his shirt"). This effect is absent from the processing of cleft negative sentences (e.g. "It is John who hasn't ironed his shirt"). When verifying a negative sentence against a picture (e.g. "the banana isn't peeled" against a peeled or whole banana), by default, the

participants tend to infer and represent the situation that makes the sentence true (e.g. inferring that a whole banana would make the sentence true) and compare it with the picture. However, the accommodated positive QUD (*whether the banana is peeled)* may encourage the development of a "truth functional" strategy, where participants no longer infer the truth condition of the negative sentence, but instead answer the positive accommodated QUD and then flip the truth value. If the negative sentence projects a prominent negative QUD (e.g. with cleft negative sentences, and when the picture context encourages a negative question), the truth functional strategy is not developed. A visual world eye-tracking study showed that while processing simple negative sentences (e.g. Matt hasn't shut his dad's window) was delayed compared to processing simple positive sentences (Matt has shut his dad's window), the processing of cleft negative sentences was no more delayed than the cleft positives. The results suggest that both QUD accommodation and the integration of the meaning of negation can happen incrementally.

More broadly, research in this thesis supports the idea that pragmatic information is incrementally updated during sentence processing, and that there is no pragmatics-free comprehension. Sentences may appear to be independent entities when we read them in an experiment or hear them "out-of-the-blue". However, for a comprehender, they are always utterances produced by a speaker and situated in a broader discourse context. We interpret utterances *in media res*: they are rarely the beginning; they are rarely -

"The End".

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Appendices

"Above /Below" data analysis for Chapter 4 experiment 4

Clark & Chase (1972) compared response times to "above" and "below" sentences. They suggested that as "above" is "normal or neutral" and "below" is "marked", it is faster to code the sentence "A is above B", than "B is below A". In a sentence first paradigm, participants will use the predicate from the sentence ("above" or "below") to code the picture. Sentence and picture representations always have the same location relation word. The mismatches can only occur in ordered pair (e.g. (star, plus)) or polarity market. Therefore, in a sentence first paradigm, "above" sentences should be responded faster than "below" in both the positive and negative conditions due to the higher frequency of "above" than "below".

On the other hand, in a picture first paradigm, the representation and comparison model is more complicated. Participants will use "above" to code the picture. A sentence with the same polarity and truth value will be responded to faster if it has "above" than "below". For example, against a picture of a plus above a star, both "the plus is above the star" and "the star is below the plus" are TA sentences. While the former has no mismatches with the picture representation. The latter has two mismatches (order pair of nouns and location word). However, instead of assuming two mismatches brings two truth index switches, Clark and Chase added the rule that a mismatch in the "embedded strings" result in a conversion in the picture representation. Confusingly, the rule is not to convert a representation with "below" into one with "above", but to convert the sentence representation that have the same order of the embedded nouns as the picture representation. For example, if the

picture is represented as (A above B), the negative sentence "B is not above A" is

first represented as "false (B above A)" and then converted to "false (A *below* B)"

(see Clark & Chase, 1972: 488 for a summary of the model). This rule seem arbitrary

and inconsistent with the sentence-first model. Why should a picture-first

representation make participants selectively convert some features of sentence

representation but not others (e,g. polarity marker)? With the complicated rules,

Clark and Chase "successfully" predicted their results, summarized in Figure 24

(copied from Clark & Chase 1972: 491).

However, in Chapter 4 experiment 4, although our participants were instructed to

read the sentence first, our RT pattern for "above" and "below" sentences (charted in

Figure 25) looks very different from the "sentence first" pattern in Figure 24. For

affirmative sentences, there is a significant truth by above/below interaction:

$F(1,39)=12.17$, $p=0.001$. In addition, there is a significant main effect of truth:

$F(1,39)=37.85$, $p<0.0001$, and above/below: $F(1,39)=9.03$, $p<0.005$. Although TA is

faster than FA for both "above" and "below" sentences, the difference is bigger for

"above" than "below". In terms of negative sentences, there is no significant truth by

above/below interaction ($p=0.11$), no main effect of truth ($p=0.9$), or of above/below

($p=0.67$).

Overall, our analysis of above/below shows a very different pattern from the

prediction or results in Clark & Chase (1972). Their prediction involved a key

assumption that in a sentence-first paradigm, sentence form (whether it has "above"

or "below") influences how pictures are coded. This claim is not supported by our

data. A sentence-graph verification study by (Feeney, Hola, & Liversedge, 2000)

also contradicted this claim: "this effect of alignment further suggests that the graph

encoding process is relatively inflexible in that information contained in the sentence does not seem to affect how the graph is initially represented" (Feeney, Hola, & Liversedge, 2000:158).
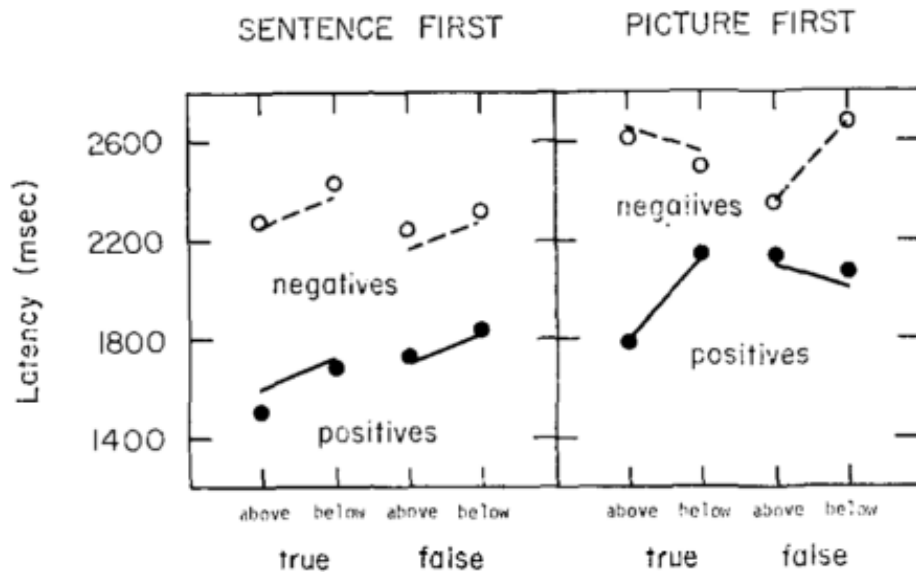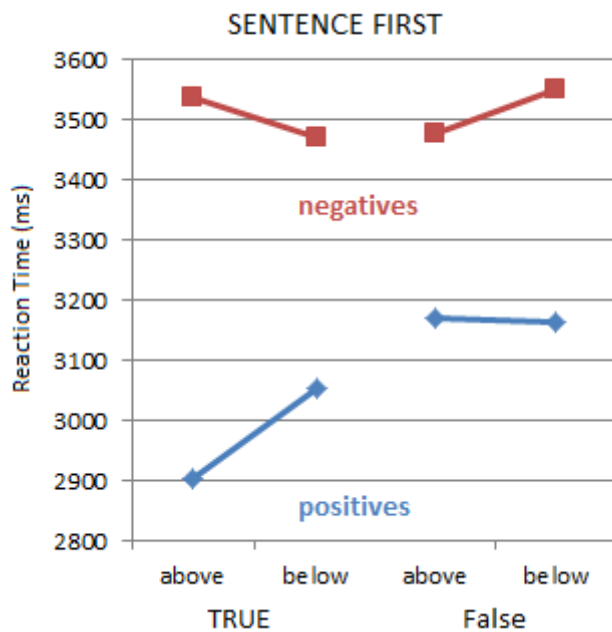

Figure 24: Observed (points) and predicted (lines) latencies in Clark & Chase (1972) Experiment II. The solid lines represent affirmative sentences, the dotted lines represent negative sentences.

Figure 25: RT by polarity, above/below and truth value - experiment 4 (observed values only)

Experimental sentences for probe recognition experiment 1 (Chapter 3)

All experimental sentences appear in simple and cleft negative form. For example "James didn't blow up his balloon" is in the simple negative condition, and "It is James who didn't blow up his balloon" is in cleft negative condition. The following list shows only sentences in simple negative form.

James didn't blow up his balloon.

Tracy didn't slice the bread.

Andrew didn't light the candle.

Mary didn't fold her deck chair.

Lee didn't seal the envelope.

Tina didn't empty the jug.

Jim didn't open the padlock.

Bill didn't tie his shoe laces.

Bob didn't roll up his sleeping mat.

John didn't inflate the tyre.

Tina didn't close her umbrella.

Edward didn't turn on the tap.

Nick didn't decorate his Christmas tree.

Chris didn't fasten the zip.

Joan didn't peeled her banana.

Chris didn't open his book.

Liz didn't close the drawer.

Sam didn't crack an egg.

William didn't melt the ice.

Sue didn't turn off the light bulb.

Ron didn't wash his car.

Jill didn't pick up the phone.

Mal didn't fold his scarf.

Jack didn't iron his shirt.

Matt didn't roll up his sleeves.

Jim didn't cook the spaghetti.

Bob didn't turn off the TV.

Fred didn't shut the window.

Experimental sentences for sentence-picture verification experiment 3 (Chapter 4)

All experimental sentences appear in positive and negative format. The following list shows only the sentence inpositive format. Items for experiment 1 and 2 are from the same list (less items). When less experimental items are used (as in experiment 1 and 2), the verbs (e.g. peel) were not repeated.

The apple isn't peeled.

The apricots aren't dried.

The balloon isn't blown up.

The banana isn't peeled.

The banana slices aren't dried.

The bat isn't flying.

The beer glass isn't full.

The bike isn't folded up.

The black bin isn't closed.

The blackboard hasn't been wiped.

The boots aren't dirty.

The bread isn't sliced.

The British flag isn't fluttering.

The butterfly isn't flying.

The cabinet isn't closed.

The candle hasn't been lit.

The car isn't washed.

The cardboard box isn't open.

The mango isn't peeled.

The map isn't folded up.

The milk bottle isn't squashed.

The motorbike isn't washed.

The mug isn't washed.

The mushrooms aren't sliced.

The oil painting isn't framed.

The onion isn't sliced

The orange isn't peeled.

The penne isn't cooked.

The peppers aren't diced.

The photo isn't framed.

The picnic basket isn't open.

The pineapple isn't sliced.

The plastic box isn't closed.

The plate isn't broken.

The potatoes aren't peeled.

The prawns aren't raw.

The carrots aren't diced.

The CD isn't scratched.

The cheese hasn't melted.

The chicken isn't raw.

The chocolate cake hasn't been cut.

The chocolate hasn't melted.

The coke can isn't squashed.

The computer isn't on.

The cricket bat isn't broken.

The cucumber isn't sliced

The cup isn't full.

The cupcake isn't iced.

The deck chair isn't folded.

The diary isn't closed.

The dictionary isn't closed.

The dishes haven't been washed.

The door isn't shut.

The drawer isn't closed.

The eagle isn't flying.

The egg isn't cracked.

The envelope isn't sealed.

The fireplace hasn't been lit.

The football isn't blown up.

The frying pan isn't empty.

The garlic isn't chopped.

The glass isn't empty.

The glove isn't wet.

The ham isn't sliced.

The ice cream hasn't melted.

The jar isn't sealed.

The jeans aren't crumpled.

The jug isn't empty.

The lantern hasn't been lit.

The rucksack isn't open.

The sandals aren't muddy.

The saucepan isn't empty.

The scarf isn't folded.

The shirt isn't crumpled.

The shoe laces aren't tied.

The sink isn't dirty.

The sleeping bag isn't rolled up.

The small pool isn't inflated.

The sock isn't wet.

The spaghetti isn't cooked.

The steak isn't raw.

The strawberry isn't sliced.

The table isn't folded.

The tennis racket isn't broken.

The tent isn't put up.

The textbook isn't closed.

The tie isn't tied.

The tissue isn't screwed up.

The tomatoes aren't dried.

The towel isn't folded.

The trainers aren't dirty.

The trousers aren't muddy.

The truck isn't clean.

The TV isn't on.

The tyre isn't inflated.

The umbrella isn't open.

The vase isn't broken.

The water bottle isn't open.

The wellies aren't clean.

The window isn't shut.

The wine glass isn't cracked.

The wooden box isn't closed.

The leeks aren't chopped.

The lentils aren't raw.

The lorry isn't clean.

The wrapping paper isn't screwed up.

The yellow pages book isn't closed.

The yoga mat isn't rolled up.

Experimental and filler sentences for eyetracking study (Chapter 5)

Experimental sentences:

All experimental sentences appear in four conditions: simple positive, simple negative, cleft positive and cleft negative. For example:

Simple positive: *Anna has closed her mom's umbrella.*

Simple negative: *Anma hasn't closed her mom's umbrella.*

Cleft positive: *It is Anna who has closed her mom's umbrella.*

Cleft negative: *It is Anna hasn't closed her mom's umbrella.*

The following list are shown in simple negative format.

Anna hasn't closed her mom's umbrella.

Daniel hasn't emptied his mum's saucepan.

Dave hasn't cleaned his wife's wellies.

Grant hasn't sliced his chef's cucumber.

John hasn't ironed his father's shirt.

John hasn't opened his friend's book.

John hasn't turned off his uncle's TV.

Matt hasn't shut his dad's window.

Mike hasn't folded his wife's scarf.

Aiden hasn't washed his dad's car.

Edward hasn't turned on his friend's tap.

Gavin hasn't opened his son's can.

Jim hasn't opened his friend's padlock.

Mary hasn't folded her friend's deck chair.

Sophie hasn't closed her sister's drawer.

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Tina hasn't emptied her mom's jug.

Tracy hasn't sliced her mom's bread.

Amy hasn't finished her cousin's jigsaw puzzle.

Andrew hasn't lit his auntie's candle.

Ben hasn't broken his friend's pencil.

Bill hasn't tied his son's shoe laces.

Chris hasn't fastened his son's zip.

Dave hasn't peeled his sister's banana.

Emma hasn't rolled up her son's sleeves.

Ian hasn't cooked his sister's spaghetti.

James hasn't blown up his cousin's balloon.

James hasn't inflated his brother's tyre.

Jessica hasn't picked up her husband's phone.

Justin hasn't erased his teacher's blackboard.

Lee hasn't sealed his boss's envelope.

Lilly hasn't cracked her sister's egg.

Linda hasn't iced her auntie's cupcake.

Lucas hasn't turned off his wife's light bulb.

Lucy hasn't framed her sister's photo.

Nathan hasn't emptied his colleague's truck.

Nick hasn't decorated his friend's Christmas tree.

Paul hasn't dried his auntie's tomatoes.

Rita hasn't screwed up her sister's wrapping paper.

Susan hasn't mended her son's jeans.

Susan hasn't rolled up her friend's yoga mat.

Zoey hasn't cut her sister's cake.

Filler sentences:

Alice shouldn't have thrown away her ice cream.

Alison will charge her brother's batteries.

Andrew will ride his father's horse.

Austin shouldn't have soaked the paint brush.

Bill has wrapped the birthday present.

Bob will chop his father's wood.

Caroline shoud have lit her dauther's lantern.

Conner shouldn't have dropped his wife's lipstick.

Eva shouldn't have scratched her brother's CD.

Gina should have picked up her baby.

Grace shouldn't have broken her boss's vase.

It is Amy who will wear a pair of high heeled shoes.

It is Ayden who shouldn't have painted his cousin's chair.

It is Ben who will build a clever robot.

It is Betty who shouldn't have cut her friend's rope.

It is Claire who shouldn't have taken off her coat.

It is Emily who should have fed the hungry cat

It is Jane who shouldn't have pushed the new trolley.

It is Jane who will catch the young rabbit.

It is Jill who will visit the new library.

It is Kylie who shouldn't have picked her uncle's grapes.

It is Lily who should have baked a pie.

It is Lucas who shouldn't have fried the fresh egg.

It is Lucy who should have watered her Dad's flower.

It is Luis who shouldn't have polished his shoes.

It is Max who should have sent his mother some flowers.

It is Molly who shouldn't have sliced her auntie's pineapple.

It is Ruth who shouldn't have eaten the fresh apple.

It is Sam who will learn to play the violin.

It is Sophie who shouldn't have drained her pasta.

It is Sue who should have knitted a new scarf.

Jack shouldn't have made a plain cup of coffee.

James will throw his new frisbee.

Kevin shouldn't have drunk his girlfriend's juice.

Luke shouldn't have lit his beloved smoking pipe.

Mia shouldn't have torn her boyfriend's diary.

Michael will melt his friend's ice cube.

Ryan shouldn't have shaved his poor dog.

Tom should have fixed his uncle's fridge.

William should have made a birthday card.