

Pragmatics and negative sentence processing

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Negation is a universal phenomenon in human communication. All natural languages have negation, yet it seems to be absent in 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). It has long been of interest to logicians and philosophers, and relatively recently of psycholinguists and pragmatists. In terms of the processing of negation, psycholinguistics studies have shown two effects that call for an explanation: the first is the asymmetry between its frequent use in natural language and its apparent processing costs often reported in psycholinguistics studies; the second is the finding that in early stages of processing, negation seems to be ignored and attention seems to be focused on its positive argument. In terms of pragmatic functions, it’s been shown that despite its simple semantic meaning, negation interacts with context to produce rich pragmatic effects. Both negation processing and its pragmatic functions present puzzles that cannot be explained by its semantic function.

This chapter reviews experimental research on sentential negation. We first survey studies on negation processing (section 1-3) and the pragmatic effects of negation (section 4). We then discuss theories of negation processing and evaluate them against empirical findings (section 5). Finally we wrap up the discussion by looking at what negation processing can tell us about the role of pragmatics in sentence processing in general.

1.1 Negation processing: the extra effort and the role of the positive argument

Psycholinguistics research into negation focuses on the asymmetry in processing cost between negative sentences and their positive counterparts. (1) is an example of a negative sentence and (2) is its positive counterpart. Here negation scopes over the embedded positive sentence “the door is open”, which is called the “positive argument” or the “positive counterpart” of the negative sentence.

- 1) The door is not open. > Not (the door is open).
- 2) The door is open.

Negative sentences are found to be more difficult to process than positive sentences. Negation-related difficulty has been found in paradigms such as sentence completion (e.g. Wason, 1961), sentence verification (e.g. Carpenter & Just, 1975; Clark & Chase, 1972; Mayo, Schul, & Burnstein, 2004), logical reasoning (e.g. Evans, Clibbens, & Rood, 1996; Oaksford & Stenning, 1992; Prado & Noveck, 2006) and inference drawing (e.g. Hovland & Weiss, 1953), manifested by longer response times and higher error rates for negative sentences, compared to their positive counterparts. Also, the memory of negated information is worse than that of positive material (e.g. Cornish & Wason, 1970; Howard, 1975). The difficulty of negation observed in these behavioral studies was also reflected in ERP and fMRI studies (e.g. Reichle, Carpenter, & Just, 2000; Tettamanti et al., 2008; Tomasino, Weiss, & Fink, 2010).

Psychologist Paul Wason conducted a series of experiments on negation processing in the 1950s and 1960s studying negative sentence verification and completion. In his 1961 study (Wason, 1961), participants were asked to complete sentences such as (3) to (6) to make them true or false, or to verify sentences in this form. Though (3) and (6) are logically equivalent, and so are (4) and (5), negative items such as (4) and (6) induced higher error rates and longer response times compared to positive items such as (3) and (5).

- 3) ... is an even number.
- 4) ... is not an even number.
- 5) ... is an odd number.
- 6) ... is not an odd number.

A similar effect has been found in other sentence verification studies. These studies either involve verifying positive and negative sentences against world knowledge, such as "an elephant is not a mammal" (e.g. Mckinsty, Dale, & Spivey, 2008; Wales & Grieve, 1969; Wason, 1961), or involve verifying sentences against pictures, such as the sentence "the dots are not red" against an image of red or black dots (e.g. Carpenter & Just, 1975; Clark & Chase, 1972; Gough, 1965; Trabasso & Rollins, 1971). In these studies, negative sentences have longer response times and higher error rates than positive sentences. A neuroimaging study by Carpenter, Just, Keller, Eddy, and Thulborn (1999) found that in a sentence-picture verification task, compared to positive counterparts, negative sentences induce increased activation in areas of the brain that are responsible for language comprehension (left posterior temporal gyrus) and for visuo-spatial processing (left and right parietal regions) (see also Fischler, Bloom, Childers, Roucos, & Perry, 1983; Herbert & Kübler, 2011; Reichle, Carpenter, & Just, 2000).

Not only does negation make sentence verification difficult, it also makes logical reasoning difficult. One famous negation-related reasoning bias is the “matching bias” (Evans, 1972; Evans, Clibbens, & Rood, 1996; Evans, 1998, and similarly Wason & Johnson-Laird, 1972). Participants evaluate conditional rules such as “if there is not an ‘A’ then there is not a ‘2’” against pairs of letters and numbers. Participants tend to look for elements that have been mentioned in the rule (“A” cards and “2” cards), even when those elements are negated. They have difficulty detecting that the pair “P” “4” falsifies the rule “if there is not an ‘A’ then there is a 6”. Evans (1998) suggests that the “matching bias” can be explained by interpretation heuristics related to the function of negation, which he called 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). When participants read a negative construction they do not automatically construct the complement set. Rather, the positive argument remains the focus of attention. Oaksford and colleagues (Oaksford & Stenning, 1992; Oaksford & Moussakowski, 2004) argue that negation does automatically trigger the construction of a contrast set, though the construction can be difficult when a large number of possible states of affairs is involved. Prado and Noveck (2006) tested these two accounts using the conditional rule task. Participants verified sentences about letters and shapes such as “if there is an H then there is not a square” against letters presented in geometric shapes (e.g. an H inside a circle). Participants were faster and more accurate to decide that H-in-a-square contravenes the rule, than to decide that H-in-a-circle complies with the rule, suggesting that negation does not automatically prime a search for the alternatives.

1.2 The representation of the positive argument: when it happens and when it doesn’t

In addition to the difficulty of negation, another prevalent finding concerns the role of the positive argument in negation processing. Studies found that in the early processing stage, negation seems to be ignored and negative sentences seem to be processed as if they were positive (e.g. Dale & Duran, 2011; Fischler et al., 1983; Hasson & Glucksberg, 2006; Kaup, Yaxley, Madden, Zwaan, & Lüdtke, 2007; Lüdtke, Friedrich, De Filippis, & Kaup, 2008). This effect has been found in probe recognition tasks, in sentence verification, and in ERP studies.

A series of studies used a probe recognition task, which tests the activation level of the representation of certain targets. Kaup and colleagues (Kaup, Yaxley, et al., 2007; Kaup, Zwaan, & Lüdtke, 2006) found that shortly after reading a negative sentence, participants simulate the situation consistent with the sentence’s positive argument. For example, 250ms after reading “the door isn’t open”, participants were faster to respond to an image of an open door than a closed door. This effect was reversed later on (at 1500ms latency). Hasson and Glucksberg (2006) studied the comprehension of negated metaphors. They

tested the activation level of probe words consistent with the metaphor's vehicle (e.g. "strong") after reading positive or negative sentences (e.g. my brother is (not) a rock). They found that for positive metaphor, response times to vehicle-consistent words were facilitated at all latencies. For negative metaphors, there was similar facilitation of the positive metaphor meaning at short latencies (at 150ms and 500ms delays), suggesting that participants initially represent the positive argument of the negative metaphor, and later suppress it.

In sentence verification, studies found that negation not only makes verification more costly, it can sometimes interact with sentence truth value: while verifying true positives is always faster than verifying false positives, verifying true negatives can be less, equally or more difficult than verifying false negatives (Arroyo, 1982; Carpenter & Just, 1975; Clark & Chase, 1972; Gough, 1966; Kaup, Zwaan, & Lüdtke, 2005; Lüdtke et al., 2008; Mayo et al., 2004; Trabasso & Rollins, 1971; Young & Chase, 1971). For example, in Clark and Chase (1972), sentences such as (7) to (10) were shown alongside a picture that makes the sentence true or false, such as a plus above a star. Verifying True Negatives (TN) takes longer than verifying False Negatives (FN), and this result was interpreted in terms of a strategy based on the truth-functional property of negation: negation reverses the truth value of a proposition. When verifying a negative sentence against a picture, participants first represent and evaluate the truth value of its positive argument, and then reverse the truth value. The initial focus on the positive argument was also found in a mouse tracking study by Dale and Duran (2011, experiment 1) and Mckinstry et al. (2008).

- 7) The plus is above the star. (True Affirmative, abbrev as TA)
- 8) The star is above the plus. (False Affirmative, FA)
- 9) The star isn't above the plus. (True Negative, TN)
- 10) The plus isn't above the star.(False Negative, FN)

ERP studies (Fischler et al., 1983; Lüdtke et al., 2008) found that certain kinds of TN sentences (e.g. "a robin is not a tree") gave rise to greater N400 effects than corresponding FN sentences ("a robin is not a bird"), while the corresponding FA ("a robin is a tree") predictably gave rise to greater N400 effects relative to TA ("a robin is a bird"). 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. 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 a picture with no ghost. At 1500ms delay, pictures that are consistent with the sentence meaning are primed more than inconsistent pictures.

These results have been interpreted as showing that processing the positive argument is the first stage of negation processing.

While it seems that participants often represent the positive argument during negation processing, some studies show that they do not always do so (e.g. Dale & Duran, 2011; Nieuwland & Kuperberg, 2008; Orenes, Beltrán, & Santamaría, 2014; Tian, Breheny, & Ferguson, 2010). In the ERP literature, Nieuwland and Kuperberg (2008) found that contextually felicitous TN do not give rise to a greater N400 effect compared to either TA or FN. 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 a 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”, “safe” elicited a *smaller* N400 than “dangerous”. They concluded 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.

Dale & Duran (2011, Experiments 2 & 3) showed that the more contextual support that the items have, the less the tendency to first consider the positive argument. 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 were easier to verify than false statements regardless of the sentence polarity. fMRI studies (Tettamanti et al., 2008) show that when reading sentences with action verbs (e.g. ‘grip’, ‘clasp’), the motor regions (left-hemispheric action-representation system) were activated during positive sentences but not negative sentences (see also Tomasino, Weiss, & Fink, 2010). Tian, Breheny, & Ferguson (2010) used a picture recognition paradigm similar to Kaup et al. (2007), but compared the processing of simple versus cleft negation sentences. They found that 250ms after the presentation of a simple negative sentence (e.g. “John hasn’t ironed his shirt”), participants responded faster to a picture that is consistent with the positive argument of negation (an ironed shirt), but that 250ms after the presentation of a cleft negative sentence (e.g. “It is John who hasn’t ironed his shirt”), participants responded faster to a picture that is consistent with the negative sentence meaning (a crumpled shirt). This shows that sentence form can somehow affect how a negative sentence is processed. When they changed the negative sentence form but not the propositional content, participants no longer showed a response advantage for the picture that is consistent with the positive counterpart. Tian et al. argued that the change of linguistic form to a cleft sentence causes a change of accommodated context.

A sentence-picture verification study by Tian and Breheny (under review) tested how picture context affects the verification strategy. Participants verified 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 prominent Question Under Discussion (QUD). With one-object pictures, the prominent QUD is positive (*whether the banana is peeled*); with two-object pictures, the prominent QUD is negative (*which one isn’t peeled*). They found that with pictures of one object, the verification of True Negative (TN) was faster than False Negative (FN) in the early phase of the experiment, but this difference diminished in later trials, suggesting a strategy in which the positive argument was first evaluated developed in the course of the experiment; with pictures of two objects, TN was faster than FN throughout the experiment, suggesting that participants did not first consider the positive argument, but inferred the state of affairs consistent with the negative sentence, and verified this inferred state against the picture.

1.3 Negation is not difficult with context

By now we have seen many different findings suggesting that negation is difficult to process. However, the majority of these studies tested negation processing without context. Many studies show that with appropriate contextual support, negative sentences are not difficult to process (e.g. Dale & Duran, 2011 experiment 3; Giora, 2006; Nieuwland & Kuperberg, 2008; Orenes, Moxey, Scheepers, & Santamaría, 2016).

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, when describing the properties of an object, it is easier to say that an item from a minority set does not have the property of the majority set, than the other way round. This was tested in Wason (1965) where participants were shown an array of eight circles, seven of which were in one colour and one in another. Participants completed sentences in the “exceptionality condition” such as “circle No. 4 is (not) ...”, or in the “ratio condition” such as “exactly one/ seven circle(s) is/are (not)...”. Wason found that sentence completion is faster when the negative sentence describes the exception item in the “exceptionality” condition than in the “ratio” condition. He attributed this difference to the coding stage. When participants coded the array in the “exceptionality” condition, the properties of the special circle are 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 group of the complement set. The fact that negation processing is faster in the “exceptionality” condition than in the “ratio”

condition suggests 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 type of relevance 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 negation often involves extra processing cost due to under-informativeness. Stand-alone negative sentences are often more ambiguous than their positive counterparts, therefore they are not effective for introducing new information (e.g. being discourse-initial). When negation is supported by context, 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. In the experiment, participants read passages such as (11). Results showed that with non-supporting context, negative critical sentences took significantly longer to read than positives. With supporting context, there was no difference between negatives and positives, suggesting that negative sentences need not be difficult to process when there is contextual support.

11) **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.*

A similar study was conducted by Lüdtke & Kaup (2006). They propose 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 (e.g. 12)) containing a positive or negative sentence preceded by different context sentences. They found that the 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 the context strongly implies a positive expectation, negation cost is completely eliminated.

12) *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.

1.4 Negation has rich pragmatic effects

The pragmatic significance of negation is reflected in at least two areas: 1) negative utterances have more specific contextual requirements than their positive counterparts. Out-of-context negative sentences warrant more background inferences; 2) negation's contribution to utterance meaning is more than reversing the truth value of a proposition: a doubly negated sentence is not synonymous with its positive version; a negated sentence often doesn't convey the opposite of its positive counterpart.

First, negative utterances have more specific contextual requirements than their positive counterparts; they are rarely used "out-of-the-blue" (that is, they rarely appear in discourse-initial position). Russell (1948) said that "perception only gives rise to a negative judgment when the correlative positive judgment has already been made or considered". 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; denials are used to reverse the truth of a proposition. This means that for negative utterances to be felicitous, the target of rejection or denial has to be in the context. When such information is not in the context, negative utterances warrant rich inferences about the background. 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", 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 suggests that accessing specific contextual information and/or drawing inferences about the context is integral to negative utterance interpretation.

Second, negation's contribution to utterance meaning is often not (or not just) reversing the truth value of a proposition. Doubly negated constructions tend to communicate a weaker scale than their positive counterparts. Horn (1989: Chapter 5) discussed several examples: a door mat of "NOT UNWELCOME" is less welcoming than "WELCOME"; commenting that someone was "certainly not unjust" is less positive than saying s/he was "just" (Horn, 1989: 303). Also, the meaning of negation depends on the frequency/markedness of the predicate under its scope. "Not happy" often communicates the opposite of

“happy”, i.e. “sad”, while “not sad” tend to communicate a medial state between happy and sad (see more discussion in Horn, 1989: Chapter 5).

Taking stock, we have surveyed studies on negation processing and pragmatic effects of negation. Processing-wise, many psycholinguistic studies have shown that negative sentences are more costly to process than their positive counterparts. The extra cost manifests in longer reading times, longer response times in sentence verification tasks, higher error rates, and worse performance in logical reasoning when negation is involved. When there is contextual support the extra costs of negation are reduced or eliminated. In addition, studies show that in the early stages of negation processing, its positive argument is often, but not always represented. Specifically, this happens when simple negative sentences are processed without context, but does not happen when linguistic context makes a negative sentence “natural”, or when external (e.g. picture) context changes the relevance of a negative sentence, or when sentence form focuses on a constituent other than negation (e.g. a focus of the subject in cleft sentences). Pragmatically, negation does more than reversing the truth value of a proposition. Negation has stricter context requirements than its positive counterpart, and out-of-the-blue negative constructions warrant rich background inferences. The meaning contribution of negation also depends on the frequency/markedness of the predicate under its scope.

These effects call for a theory of negative sentence processing that can answer these three questions: why are negative sentences difficult to process (at least in psycholinguistic experiments)? Why is the representation of the positive counterpart often but not always involved? How does negation allow us to infer such background information?

1.5 Accounts of negative sentence processing

1.5.1 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 on the function of negation as a truth-functional 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. We will call these accounts rejection accounts.

Rejection accounts can be roughly divided into propositional models and simulation accounts, differing in the nature of representation that they posit. Propositional models were proposed to account for the

polarity by truth-value interaction in sentence verification (Carpenter & Just, 1975; Clark & Chase, 1972). The models say that negative sentences are represented in a propositional format where a positive argument is embedded under a negative operator. For example, the sentence “A is not above B” is represented as “Not (above [A, B])”. The content of the positive argument is evaluated first, only after which can the meaning of negation be incorporated. The extra embedding step explains why negative sentences take longer to process than positive ones. A similar model was proposed by Khemlani, Orenes and Johnson-Laird (2012), according to which negative sentences are represented by a negative operator that takes the extension of the positive argument, and returns its complement set. 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. This approach thus predicts less processing cost when the complement set contains fewer members. For example, “the cat is not dead” should be processed faster than “the cat is not black”.

In comparison, the two-step simulation account (Kaup, Zwaan, & Lüdtke, 2007) agrees with the idea of embedding the positive counterpart, but states that mental representations are perceptual in nature. It 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 of both concrete and abstract concepts are perceptual in nature, i.e. they are similar to representations constructed in nonlinguistic cognition, using sensorimotor systems. 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 a simulation consistent with the sentence meaning. The meaning of negation 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). Like propositional models, the two-step simulation account explains the processing cost of negation in terms of the extra step of simulation. 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 remains to be done is rejecting the first simulation and simulating the actual situation. The theory thus predicts that when the prior context contains the positive argument, negative sentences take less time to process.

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 find that representing the positive counterpart is not mandatory, sometimes even when the sentences are

presented without context (Tian et al., 2010). 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. 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 food (Altmann & Kamide, 1999). Recently, research into the online integration of pragmatic information has also grown. 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). Pragmatic 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.

1.5.2 Contextual approach

The contextual approach focuses on the importance of context for negation processing (Wason, 1965; Horn, 1989; Givón, 1978; Leech, 1981; Nieuwland & Kuperberg, 2008). The main idea of this approach is that without context, negative utterances have two pragmatic drawbacks: infelicity and under-informativeness. The infelicity of negation out of context was discussed by Wason (1965), who argues that negative utterances are often used to deny or contradict a positive proposition. Therefore, negative sentences out of appropriate context are often infelicitous, and therefore hard to process. 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 not red" has indeterminate verification conditions. 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 Gricean maxim "being informative" (Grice, 1975). 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".

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'. That is, "the door is open", just like "the door is not closed", is typically produced only 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, it is found that when we process negative sentences, the positive argument of a negative sentence is often represented during the early processing stages. No contextual account so far explains why when lacking contextual support, the positive argument *is* represented in the first place.

1.5.3 Dynamic pragmatic account

The dynamic pragmatic account (Tian et al., 2010; Tian, Ferguson, & Breheny, 2016) is a contextual theory that specifies exactly how negation interacts with context, whether an explicit context was provided or not. Following on from the observations from the contextual approach, it seems clear that there are differences in how negative sentences interact with context compared to positive sentences. The dynamic pragmatic account argues that the processing effects have a pragmatic cause, even though in the majority of the relevant psycholinguistic studies, no context was explicitly provided.

The dynamic pragmatic account brings together two well-established assumptions in language research. From formal semantics/pragmatics, we assume that language use functions to update a shared information state, called a 'context'. Thus meaning, in a more extended sense, is a function from input states to output states (Stalnaker, 1979; Kamp, 1981; Sperber & Wilson, 1986). Furthermore, the states that are updated contain not only information that is taken for granted (common ground), but also information about the interaction itself – the current goals of the interlocutors, what issues are under discussion and so forth. Interlocutors aim to achieve relevance and this is typically modelled in terms of a notion of Question

Under Discussion (QUD) (Ginzburg, 2012; Roberts, 2012). Thus, it is useful to describe a speaker's aims in terms of addressing a prominent Question Under Discussion.

A second assumption of the dynamic pragmatic account of negation comes from language processing research – that interpretation is incremental (Altmann & Steedman, 1988; Kamide, Altmann, & Haywood, 2003; van Berkum, Brown, Zwitterlood, Kooijman, & Hagoort, 2005). This means that tentative decisions about utterance interpretation are made as the utterance itself proceeds.

Putting dynamic pragmatics and incrementality together, the dynamic pragmatic approach assumes that incremental language processing systems make decisions not only about the semantic content of an utterance, but also about the likely source of relevance, or QUD, for an utterance. Clifton and Frazier (2012) demonstrate that QUD mismatch interferes with on-line reading processes (see also Clifton & Frazier, 2016).

Decisions about the intended update often involve accommodation of context – both of background assumptions and of QUDs (Ginzburg, 2012; Roberts, 2012; Stalnaker, 2002). Thus participants presented with a context-less sentence will make some inferences about the likely intended source of relevance (or QUD) as well as likely presuppositions or background information that such a sentence normally would carry.

The dynamic pragmatic approach argues that negation is a cue for retrieving a prominent positive QUD. Without other cues, the most prominent QUD for a negative sentence 'not p' is the positive polar question *whether p*. This is due to the most frequent uses of negation (rejection and denial), but 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. That is, in the absence of other cues, upon hearing a negative sentence such as "John hasn't ...", we tend to activate the prominent QUD is "whether John has...", This form of on-line 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. 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.

1.5.4 Evaluating theories of negation processing against empirical findings

Before presenting theories of negation processing, we summarized three key empirical findings: (i) negative sentences are often reported more difficult to process; (ii) in early processing stages, the positive argument is often but not always represented; (iii) contextual support can eliminate the above two effects, and out-of-context negative utterances warrant rich pragmatic inferences. Rejection accounts can fully explain (i) and partially explain (ii) and (iii), but they cannot explain why the positive argument is not always represented. General contextual accounts can explain (i) and (iii), but do not explicitly explain why the positive argument *is* sometimes represented. The QUD accommodation account can explain these effects: without context support, sentential negation $\neg p$ triggers the accommodation of a positive QUD *whether p*. However, what QUD gets accommodated is influenced by top-down contextual and linguistic cues (e.g. visual context, cleft construction, prosodic focus of the constituent other than negation). The conflicting representation of the positive QUD and the negative sentence meaning contributes to the extra processing cost. The accommodated QUD gives rise to contextual inferences.

What about the time course of negation processing? Rejection accounts predict that the activation of the positive argument is short-lived, and negation cannot be incorporated until the positive argument is processed. In comparison, the QUD accommodation account predicts incremental incorporation of negation, and is noncommittal about how long the accommodated positive QUD can be active. Autry and Levine (2012) tested how contexts affect the activation of the negated concept (the positive argument). They found that when there is no contextual support, the negated concept (the positive argument) is activated for a prolonged period of time. This result is inconsistent with the rejection accounts, according to which the representation of the positive argument is a first and short-lived step. However, the QUD accommodation account can explain this result. When negation is not licensed, participants accommodate a positive QUD, and they can reasonably expect this QUD to be the topic of the upcoming discourse.

Tian et al. (2016) tested when the positive argument is represented, and when the meaning of negation is integrated, during out-of-context negative sentence processing. In a visual world paradigm, participants listened to positive and negative sentences in simple or cleft forms (e.g. [It is] Matt [who] hasn't shut his dad's window), while looking at scenes containing a target and a competitor (the target matches the implied shape of the noun, while the competitor mismatches it). They found that in the simple but not the cleft condition, there is a difference between negatives and positives: shortly after the verb, there are more looks to the competitor in the simple negatives than the positives. They concluded that the representation of the positive is not a mandatory first step of negation processing. Rather, both sentence content and contextual source of relevance (QUD) are processed incrementally.

1.5.5 General implications and future directions

Research on negative sentence processing has both methodological and theoretical implications for the study of sentence/ utterance comprehension in general. 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. We have seen that when negative sentences are presented without context, participants automatically retrieve and accommodate relevant contextual information. Sentence comprehension is never independent from contextual effects. This finding suggests that when we design psycholinguistic experiments and interpret their results, we must consider the likely pragmatic processes, and how they interact with the processing of the sentences' linguistically coded meaning.

Theoretically, the research on negation processing and the effect of context 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). #### probably add references from the volume here.

This chapter covers a small sample of research on negative sentence processing. There are many open questions remain: what (different) effects will we observe in the processing of implicit negation, embedded negation and negative quantifiers? How can different theories of sentential negation deal with these phenomenon? What are the pragmatic effects of negation in polar questions? How does negation influence memory? How does it interact with reasoning? How are negative utterances processed by young children? Or by comprehenders with autistic spectrum disorder? We hope more researchers join our quest, as we believe understanding negation is an important albeit small piece of understanding the part of cognition that is uniquely human.

1.6 Conclusion:

This chapter surveyed studies of negation processing. 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. We reviewed three theories of negation: rejection accounts, a general contextual approach, and a dynamic pragmatic account.

The dynamic account can explain the processing and pragmatic effects of negation. More broadly, these findings are consistent with the idea that pragmatic information is incrementally updated during sentence processing, and that there is no pragmatics-free comprehension.

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