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Words, pictures and sentences

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Words, pictures and sentences

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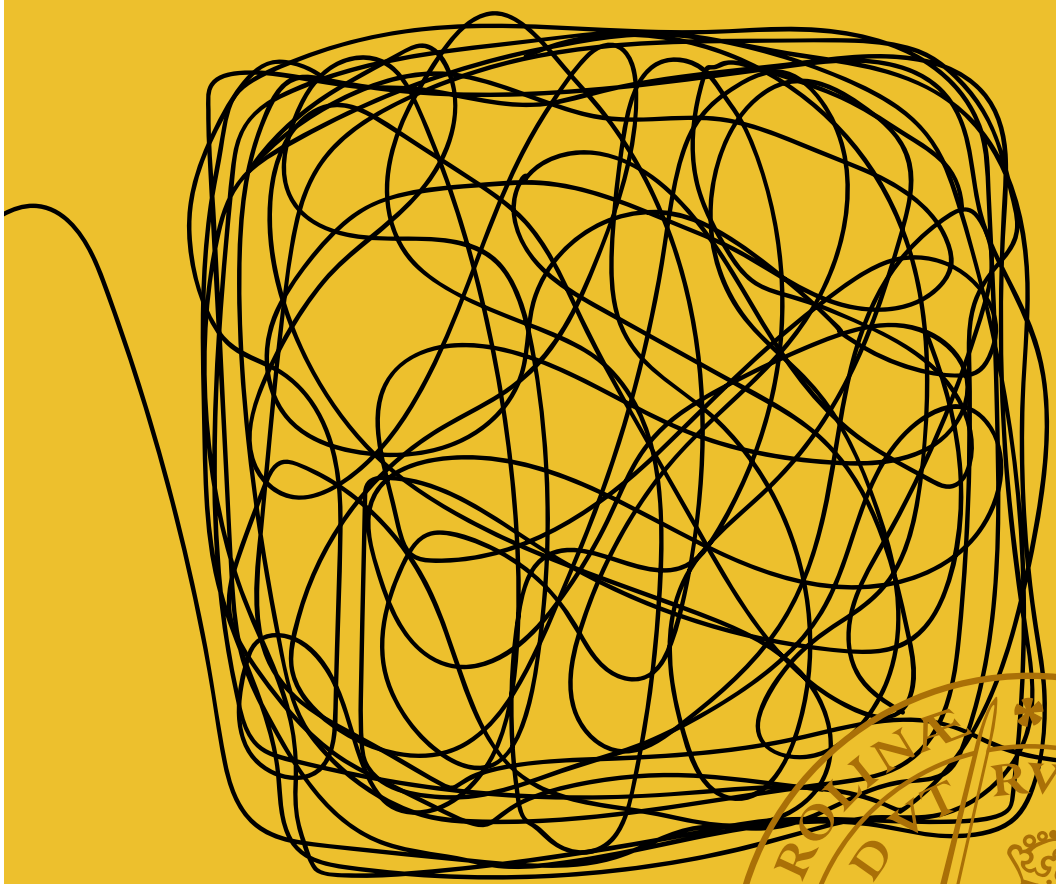

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Neural and behavioural mechanisms underlying the processing of negated meanings

Words, pictures and sentences

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Title and subtitle
Neural and behavioural mechanisms underlying the processing of negated meanings: words, pictures and sentences

Abstract

This thesis combines a number of methodologies and measures in order to address the processing of two types of negation (with *not* and *un*) in relation to each other and to non-negated affirmative meanings. The four investigations in this thesis target the processing of these meanings at different levels, namely the word level (Study 1) and sentence level (Studies 2–4).

In two artificial language learning experiments, Study 1 focuses on the cognitive operations behind the processing of the negated meanings expressed by *not* and *un* in English. Negated and non-negated meanings are presented through artificial prefixes in order to do away with factors inherent to natural language (i.e., frequency and length). The meaning ranges associated with the negated types are manipulated and tested. The results reveal that the processing difficulty of these negation types can be modulated by the scopal ranges that they cover. This study can be taken to serve as a baseline for the future research on the processing of negated meanings that involve similar cognitive operations.

Using event-related brain potentials (ERPs), Studies 2–4 target the time-course of processing negation in sentence comprehension. Affirmative, prefixally negated and sententially negated adjectives (*authorized, unauthorized, not authorized*) are presented in complex sentential contexts using both visual (Study 2 and Study 4) and auditory (Study 3) stimuli. The results of these investigations reveal a number of discursive factors that modulate the processing of these forms in sentence comprehension. More specifically, the results reveal that factors such as visual or auditory input, order of presentation, relevance and immediacy of the information presented all affect the processing of negated meanings in context.

Overall, the findings of the studies in this thesis contribute new knowledge to a dynamic view of meaning and language processing and suggest that the processing of negated meanings, similar to many other linguistic phenomena, is not only sensitive to the properties of individual words and expressions but is also modulated by contextual factors.

Key words
negation, scalar meanings, artificial language learning, EEG, ERP, semantic incongruities, N400, P600, sentence processing, auditory processing

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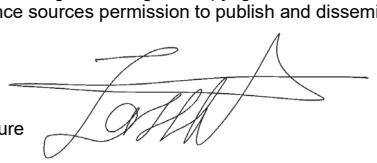
Signature 

Date 1 August 2019

Neural and behavioural mechanisms underlying the processing of negated meanings

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To my family

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Acknowledgement

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Abstract

This thesis combines a number of methodologies and measures in order to address the processing of two types of negation (with *not* and *un*) in relation to each other and to non-negated affirmative meanings. The four investigations in this thesis target the processing of these meanings at different levels, namely the word level (Study 1) and sentence level (Studies 2–4).

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List of papers

This thesis is based on the following studies:

Study 1
Farshchi, S., Andersson, R., van de Weijer, J., & Paradis, C. (2019). Processing negation in a miniature artificial language. *Cognitive Science, 43*. doi: 10.1111/cogs.12720[1]

Study 2
Farshchi, S., Andersson, A., van de Weijer, J., & Paradis, C. (under review). Processing sentences with sentential and prefixal negation: An event-related potential study.

Study 3
Farshchi, S., Andersson, A., van de Weijer, J., & Paradis, C. (submitted). Event-related brain potentials to the auditory processing of incongruities in negated and affirmative sentences.

Study 4
Farshchi, S., Andersson, A., van de Weijer, J., & Paradis, C. (manuscript). Order of presentation affects the processing of negation: An ERP study

In all four studies, I am the main author, which means that I have taken the lead in all the different stages of producing the articles including: proposing the topics, developing research questions and the hypotheses, designing the experimental paradigms, carrying out the experiments and data collection, analysing the data and writing up the articles. The co-authors are my supervisors: Carita Paradis (main supervisor), Annika Andersson and Joost van de Weijer (co-supervisors), and Richard Andersson (former co-supervisor, Study 1). All the co-authors have provided continuous feedback throughout all the different stages specified above and have provided editorial input in the writing stage of the articles. Any errors or shortcomings in the articles are my own.

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1. Introduction

It is not the case that previous research on negation has not tried to provide indisputable evidence but has instead produced seemingly irreconcilable results; this thesis is not an exception. If you did not go back to read the first sentence twice, you are either a genius (unlike me) or you are reading this thesis in a sloppy manner. In either case, my ego has taken a hit.

In reviewing the first sentence again, we easily identify the source of difficulty and associate it with what we call expressions of *negation*, namely *not* and *in*/*ir*. The fascination with negation as one of the most basic and pervasive phenomena in human reasoning and communication has a very long history dating back to Plato and Aristotle's time (5^{th}-4^{th} cent. BC) when attempts were made to explain and understand negation and its role in logic and philosophy (see Horn, 1989). The study of negation did not stop with philosophy but was extended not only to language, but also to psychology, cognitive science and artificial intelligence.

What has intrigued me most—and possibly many other researchers—about negation is its versatility and usefulness in various contexts, performing multiple functions from the most basic logical operation of opposition to meaning modification of various sorts. Because of the flexibility with which negation can make radical and at the same time minimal changes to meaning, it is a useful device for various purposes in human communication. In spite of the fact that it has been studied from many different perspectives resulting in both theoretical and empirical contributions, there are still many gaps in our knowledge about the processing of negation. For instance, we do not exactly know what makes the opening statement of this section challenging to process, nor do we have enough empirical evidence of the processing of different expressions of negation in different contexts to be able to formulate a theory that captures the essence of negation as well as its versatility. There are, however, empirically-based models that have presented valuable information about the interpretation and the processing of negated expressions, which have contributed to a better understanding of the mechanisms involved in the processing of negated meanings. This means that in this thesis, I do not have to start from scratch but rather add new insights and developments to existing ones.

The broad aim of this thesis is to increase our knowledge of the processing and interpretation of negation in language. There has been a great deal of research suggesting that the processing of negated meanings is not as straightforward as the

processing of non-negated meanings. On the one hand, many experimental investigations have shown that negation induces a higher processing cost, reflected in different quantitative measures such as longer response times, lower accuracy rates and disrupted eye movements (Clark, 1969; Ferguson, Sanford, & Hartmut., 2008; Just & Carpenter, 1976; Wason, 1959). On the other hand, there are researchers who have argued that negation does not hinder language processing when used in an adequate or natural context (Arroyo, 1982; Glenberg, Robertson, Jansen, & Johnson-Glenberg, 1999; Nieuwland & Kuperberg, 2008; Wales & Grieve, 1969; Wason, 1965). This divergent evidence on negation as well as the dynamics of its application in different contexts was what sparked my interest in further exploring this topic. When I reviewed the literature on negation, it soon became clear that most of what is referred to as negation is based on research conducted on certain forms of negation such as *not*, *no* and *any,* while little is known about the nature of some other negated forms such as negating prefixes *un/il/m/r etc.*, even though these forms are typically referred to as a form of negation in the literature and in linguistic text books (e.g., Cruse, 2011; Plag, 2003). In view of the fact that prefixally negated forms constitute one third of the negated instances in spoken language and more than half of the negated instances in written language (Tottie, 1980), it seems important to understand the way these forms are perceived and processed in the brain in order to find out whether they share patterns with other negated forms or whether they have been erroneously classified as forms of negation.

In this thesis, I address this knowledge gap by focusing on the processing of negation with *not* (e.g., *not happy*, *not intentional*, *not authorized*) and with *un* (e.g., *unhappy, unintentional, unauthorized*). In order to make sound comparisons, I also make sure to include a reference point, a baseline, against which the processing of the two negated forms could be evaluated, namely, non-negated affirmative forms (e.g., *happy, intentional, authorized*) since the processing of such forms has been shown to be easier than negated forms in many contexts.

1.1. Scope and research questions

In this thesis, two expressions of negation are considered, as well as how these expressions are processed and integrated. This means that the work falls within the area of psycholinguistics in that it focuses on the relation between language and behavioural and neurophysiological factors of how human beings comprehend and interpret language. The approach to the semantics of negation is situated in the broad framework of Cognitive Linguistics, which is a usage-based theory that views meaning in language as highly dynamic and context-dependent (Talmy, 2000). In Study 1, the focus is on how (negated and non-negated) meanings of individual

words in a miniature artificial language represented by pictures are understood. Studies 2–4 explore how negated word meanings in sentences in English are processed in the brain. Among the many expressions of negation in English (*not*, *no*, *any*, *none*, *never*, *un/il/im/in/ir, few, etc.*), I focus on two types of negation, namely, negation with *not* and negation with *un*. The reasons for why these two expressions of negation are selected are: i) the need for more research on negated meanings with *not* to determine the mechanisms underlying the processing of this negation type, and ii) the scarcity of research on the processing of prefixally negated meanings with *un*. Three principal research questions are at the heart of this thesis:

RQ1. Does negation incur a processing difficulty? If yes, in what way?

RQ2. How is the processing of negated meanings modulated under highly controlled conditions (Study 1) and in the presence of a larger context (Studies 2–4)?

RQ3. What is the status of prefixally negated forms? Are they processed as a form of negation or not?

As can be seen from RQ1 and RQ2, an overarching goal here is to further explore the processing of negated meanings and the constraints that affect their processing both out of context, at the word level (Study 1) and in larger contexts resembling natural everyday statements that we encounter in, for instance, news outlets (Studies 2–4). The terms "negated meanings" and "negation" in these two RQs refer to the well-established and well-researched expression of negation, namely, *not*. The other objective here is to contribute to the status of prefixally negated words, as reflected in RQ3. As such, it is not a priori assumed that prefixally negated words are in fact a form of negation. I hope to present a data-driven answer to RQ3 that can shed new light on the processing and treatment of prefixally negated forms.

In order to address these three research questions, I break them down to smaller and more specific questions as listed in Table 1. These questions are addressed in the four different studies. In Study 1, the aim is to provide an answer to the above-mentioned research questions in two tightly controlled artificial language experiments through which I can do away with the problematics of natural language that affect the processing of negation. In this sense, Study 1 serves as a baseline for future studies of negation and can be used in the discussion of the cognitive operations underlying the processing of negated meanings.

In Studies 2–4, I move away from the low-level processing, that is, processing at the word-level, to a higher-level processing, that is, the processing of negated meanings in a larger context including combinations of clauses. In Studies 2–4, I make use of a neurophysiological technique, namely, event-related brain potentials (ERPs), by recording continuous electroencephalogram (EEG) and time-locking this EEG to the onset of a stimulus (in this case, words). This allows me to take a closer look at the detailed time-course of processing language as it unfolds in real-

time, down to milliseconds. Each study targets one aspect of processing negated meanings in context. Study 2 is an ERP study that investigates the word-by-word reading of sentences focusing on the retrieval of negated meanings from the preceding context and their integration in the sentential structure. Study 3, in contrast, focuses on the auditory processing of negated sentences that is typically the most widespread mode of processing language input. Study 4 is yet another visual ERP study in which the order of the presentation of negated information in sentences is manipulated to target the more immediate processing of negation, as opposed to the retrieval of negated information from the preceding context in Studies 2–3. Table 1 outlines the detailed research questions that serve as the motivation for each study.

Table 1. Research questions invetigated in Studies 1-4

Study	Research questions
Study 1	RQ1. Is processing prefixally negated meanings more difficult than that of non-negated meanings when these forms are controlled for frequency and length differences?
	RQ2. Is the meaning scope associated with negation with *not* more difficult to process than the meaning scope associated with negation with *un*?
	RQ3. Does manipulating the scopal ranges associated with negated meanings by *not* and *un* affect the processing difficulty of these forms?
Study 2	RQ1. Does sentential negation (*not*) cause any difficulty for comprehension (e.g., delay in integration) or is it processed similarly to the affirmative form, as reflected by ERPs?
	RQ2. Is prefixal negation (*un*) processed similarly to sentential negation (*not*) or to the affirmative form?
Study 3	RQ1. Is there a difficulty in the auditory processing of negated sentences as reflected by ERPs?
	RQ2. Is there a difference between the auditory and visual (Study 2) processing of affirmative and negated sentences?
Study 4	RQ1. Does manipulating the relevance of the negated information in context (i.e., negation is presented at a point when the congruency of the sentence becomes clear) and hence the immediacy of negation (i.e., the negated meaning is fresh in memory and can easily be accessed) facilitate its processing?

2. Background

This section provides a summary of the theoretical background on the topic of negation including a brief overview of the negating operators *not* and *un* and their functions, previous empirical findings about the processing of these forms and the theories developed for the processing of negation within the cognitive and psycholinguistic frameworks.

2.1. What is negation?

Negation is expressed in many forms in both speech and writing and these expressions convey a range of different functions. Therefore, presenting a comprehensive account of negation is beyond the scope of this thesis. In this sub-section, I present a brief overview of one of the most common expressions of negation, namely, *not* along with its common functions and interpretations. Even though this introduction to negation focuses on the negator *not*, expressions of negation go beyond these instances and can take many shapes and forms. What exactly counts as negation is a question that has not been properly addressed in the studies investigating negation and negatives. Whether it is the presence of an explicit negator that constitutes a case of negation or the negative semantics of the word is not very clear. The term *negation* is often used to refer to words including some sort of explicit negator such as *no*, *not*, *none*, *un*, etc. Alternatively, the term *negative* is used to refer to words with negative semantics; these are words with negative meanings in relation to a positive counterpart (*forget* vs. *remember*). In this thesis, I do not deal with the concept of *negatives* but instead, operationalize negation as instantiated by the presence of an explicit negating operator (i.e., a semantic operator) such as *not* or *un* when modifying adjectives (*not happy*, *not old*, *not authorized*, *not intentional*). The interpretations arising from such uses of negation are further elaborated on in the next few sections.

Different accounts of negation have been offered throughout the years by many researchers. For instance, Horn (1989, 2010) with a formal treatment of negation, Tottie (1980, 1991) with a corpus-based treatment of negation, Giora (2006; Giora et al., 2005a, 2005b, 2007, 2008, 2009, 2015) with a psycholinguistic, discursive approach to negation, Paradis (2001, 2008; Paradis & Willners, 2006, 2011, 2013)

with a cognitive psycholinguistic approach to the perception and processing of negated antonymic meanings, Kaup (2001; Kaup et al., 2006, 2007) with a psycholinguistic approach within embodied cognition and many others have contributed to our understanding of negation. One of the very first definitions of negation was presented in the realm of logic by Aristotle in his Square of Opposition (see Horn 1989 for more details). According to this logical account, the main function of negation is reversing the truth-value of a statement, in which case *not p* equals *it-is-not-the-case-that p*, as exemplified in sentence 1 below:

1) a. The fire was *not intentional*

   b. *It is not the case that* the fire was *intentional*

This view of negation—or various versions of it—continues to be adopted in logic and philosophy as well as in formal approaches to linguistics where negation is treated as a logical operator (see Cann, 1993). However, there has been an extensive body of research indicating that this account of negation is rather limited when it comes to natural language use and understanding. It is not designed to cover all the potential functions and construals of negation. Below I will discuss some of the different uses and functions of negation in language that go beyond the logical treatment of negation.

One of the most common uses of negation in language is to reject a statement, or to voice disagreement as can be seen in example 2 (cited in Giora, 2006, p. 983):

2) ''Anything you can do I can do better

   I can do anything better than you''.

   ''*No you can't''*

   ''Yes I can''

   ''*No you can't''*

   [...]

While rejection is typically identified and discussed as negation's most natural function, Giora (2006) argues that previous research has shown that only a small percentage (8%) of all uses of negation convey rejection or disagreement. Negation has ramifications and implications for meaning-making that go beyond pure opposition and rejection; through negation we evoke a range of different meanings, from negating the existence of something to mitigating strong statements and inducing irony and metaphor (e.g., Colston, 1999; Giora, 2006; Giora, Fein, Metuki, & Stern, 2010; Holleman, 2000; Horn 2010; Paradis & Willners, 2006). For example, in a sentence such as *She is not pretty*, negation is used as a hedging operator or a mitigator as the interpretation of such expressions has been shown to be 'less than pretty' rather than outright 'ugly' (Giora, Balaban, Fein, & Alkabets,

2005a). When asked to break bad news, people tend to mitigate the message by using negation, for instance using *not succeeding* rather than *failing* in order to soften the statement (Giora, 2006). Negation has also been shown to have sarcastic uses as in *you don't say* or *Mother Theresa she is not* (Giora, Drucker, Fein, & Mendelson, 2015), or metaphoric uses as in *You are not my mother* or *Blood is not water* (Giora, 2006). Negation can also be used for emphasis in expressions such as *by no means* (Giora, 2006). It can be used in what is called "metalinguistic negation" as in *Winning isn't everything–it's the only thing*, in which case the concept that is negated is retained but its implicature is cancelled (Horn, 1989, p. 372). All of these examples testify to the versatile and powerful nature of negation as a cognitive and linguistic operator.

2.1.1. Negation, opposition and gradability

In this sub-section, I will discuss the concepts of opposition and gradability in relation to negation, as all three are closely linked and are central to our understanding of the phenomena under study in this thesis. I adopt a cognitive semantic model in the treatment of negation, which is part of a more comprehensive framework for the description and explanation of meaning making in discourse called Lexical Meaning as Ontologies and Construals (LOC, Paradis, 2005).

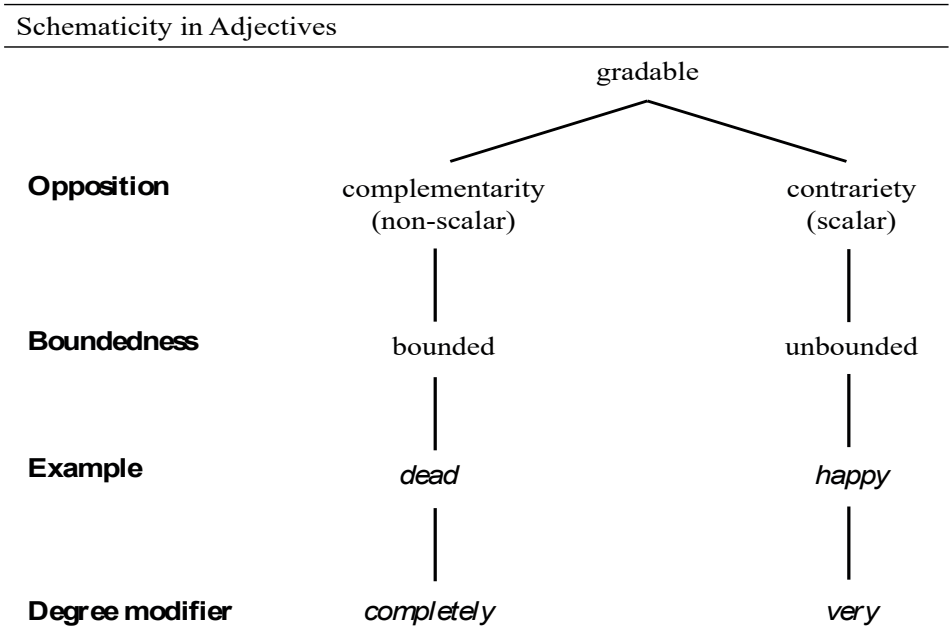
As already pointed out, negation is an extremely diverse operator that can apply to all kinds of meanings. For instance, negation can operate on nouns (*not a boy*, *not a fox*), adjectives (*not dead*, *not blue*), verbs (*not sleeping*, *not running*), etc. What negation does in principle is to define a boundary and create a construal of binary opposition, either within a domain—that is, to divide a domain into two parts with opposing properties of concepts on each side of the boundary—or to create a divide between a specific domain and what falls outside that domain. In some cases, the domain for which negation defines a boundary is clear and the two parts on each side of the boundary are symmetrical. For instance, in a sentence such as *Contrary to expectation, the new-born baby was not a boy*, the (traditional) gender domain has been divided into *boy* and *not a boy*, in which case the interpretation of the negated expression is *a girl*. Other cases of such domains include examples such as *He is not dead* where the negated expression *not dead* is interpreted as *alive*. In other cases, however, the domain for which negation sets up a boundary is not so clear. This is the case in *I am not sure what I saw on the road that night but it was not a fox* where the negated expression *not a fox* covers a wide range of animals. Similarly, in the example *He was not sleeping*, the part on the other side of the boundary could potentially cover a wide range of actions and states as in *He was working*, *He was painting*, *He was thinking etc*., which shows that that negation can be applied to different domains and meaning configurations to define a boundary and divide the domain into two opposite parts with both narrow and broad meaning

scopes. Below, I will zoom in and discuss the application of negation to adjectival meaning types, which is the focus of this thesis.

From this brief introduction, it should be clear that the hallmark of negation in language is that speakers can make use of it to create binary opposition. Now opposition is not only expressed through negation but can also be exemplified by pairs such as *big-small*. Pairs of opposites such as these refer to two opposing properties of the same dimension, that is, the dimension of size. This allows them to be content-wise similar in meaning (i.e., SIZE) but differ in signifying the opposite poles of this meaning dimension (Paradis & Willners, 2011). This characteristic of opposites (i.e., that they map on to the same meaning dimension) allows for the manipulation and testing of these meanings within the same semantic context, as has been done in the studies of this thesis. The four studies in this thesis investigate the processing of opposite negated meanings along the same meaning dimension, based on two different configurational types of meanings (e.g., AGE: *happy-unhappy-not happy* in Study 1, AUTHORIZATION: *authorized-unauthorized, not authorized* in Studies 2–4). These two configurational types differ in terms of gradability, which is a property that is sensitive to the application of negation. Below I will present a discussion of gradability and how negation applies to such meaning dimensions.

In natural language, the interpretation of a negated meaning varies depending on the configuration of the meaning it operates on, even though in all cases, negation creates a boundary between the opposing parts. Importantly, in combination with adjectival meanings, negation has been shown to be sensitive to what is referred to as the "boundedness" property of adjectives (Paradis, 2001). This boundedness property is associated with gradability, namely, whether the meaning of the adjective is configured according to a definite boundary or not. Based on this property of boundedness, adjectival meanings may be divided into two categories of bounded (non-scalar) and unbounded (scalar), as seen in Table 2. Scalar unbounded adjectives (e.g., *happy*) correspond to a range on a scale, while non-scalar bounded adjectives (*dead*) divide a conceptual domain into two distinct parts (Paradis, 2001). In terms of opposition, scalar unbounded adjectives such as *happy-sad* form pairs of contraries and non-scalar bounded adjectives such as *dead-alive* form pairs of complementaries, as shown in Table 2. These two types of adjectival meanings, namely bounded and unbounded, combine with different types of degree modifiers. Bounded non-scalar adjectives combine with totality modifiers such as *completely* (*completely dead*), while unbounded scalar adjectives combine with scalar modifiers such as *very* (*very happy*). It is important to note that this categorization is by no means a fixed dichotomy in that words do not have fixed meanings and they can be used flexibly in context to express both scalar (with or without boundaries) and non-scalar meaning types (Paradis, 2008).

Table 2. Schematicity in adjectives (adopted and modified from Paradis, 2001, p.54)



In order to further clarify the difference between the configuration of a scalar or non-scalar negated adjectival meaning, I have created Figure 1 based on the cognitive semantic model of meaning making (LOC, Paradis, 2005). As shown in Figure 1a, when negation operates on a non-scalar meaning structure such as existence, with DEAD–ALIVE as the opposing poles, there is a definite boundary between the two poles and no middle ground. Someone is either *dead* or *alive*. When on the other hand, negation operates on scalar structures, as is the case for the dimension of size in Figure 1b, with the opposite properties of SMALL–LARGE, there is a pivotal area in the middle that can be adjusted in accordance to contextual needs and demands (Paradis, 2001). These meaning structures are typically expressed by a set of gradable adjectives in languages such as English, but can of course also be construed in the form of other word classes (Paradis, 2005; Paradis & Willners, 2011; Jones, Murphy, Paradis & Willners, 2012). In the case of non-scalar bounded meanings, exemplified by DEAD–ALIVE (Figure 1a), negation (*not*) has the effect of dividing the dimension into two distinct parts, *not dead* and *not alive*, which evoke the same parts of the dimension as *alive* and *dead* respectively, that is, *not dead* is the same as *alive* and *vice versa* (Paradis & Willners, 2006). In the case of scalar unbounded meanings, exemplified by SMALL–LARGE (Figure 1b), the negator may apply to any part of the scale except for the region of the modified adjective. In other words, *not small* may in principle apply to any range along the entire scale in a given context except to the range evoked by *small*. Work on how speakers actually

interpret negated scalar meanings has shown that these meanings apply to a range on the scale that is the same as the range for the degree modifier *fairly*, that is, *not small* ranges over the same area as *fairly large*, and *not large* coincides with the range for *fairly small* from a configurational point of view (Paradis & Willners 2006, 2013). From a perceptual point of view, the structure of the scalar dimension may be symmetrical or non-symmetrical or include an intermediate range that occupies a major part or a minor part of the dimension, which also plays a role for our understanding and interpretation of these negated forms (Bianchi, Savardi, Burro, & Torquati, 2011). In the four studies of this thesis, I have made use of both scalar and non-scalar meaning dimensions in testing the two negation types *not* and *un*. More details on the selection of scalar (Study 1) or non-scalar (Studies 2–4) adjectives across the studies will be presented in Section 3.3.

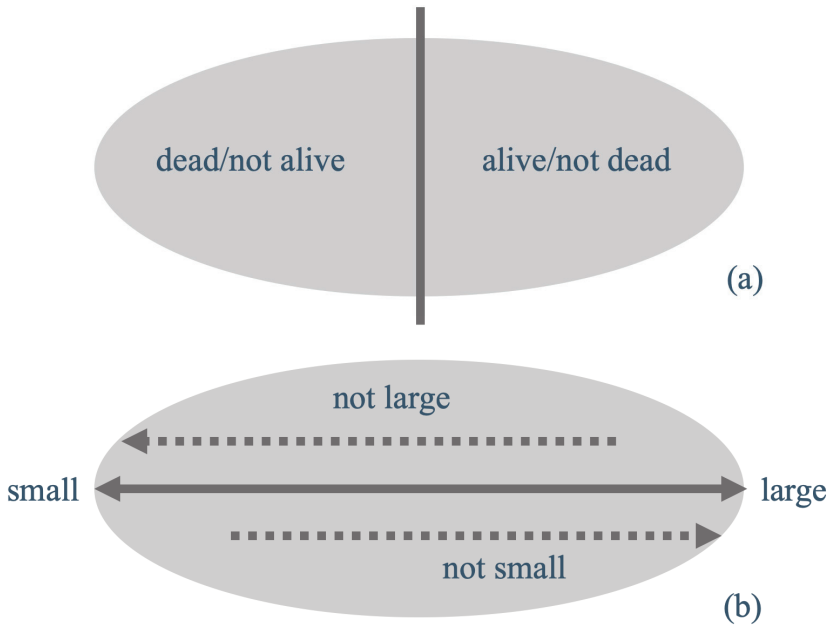


Figure 1. A configuration of the meaning dimensions by bounded and unbounded adjectives. Negation applies differently to bounded adjectives (a) and unbounded adjectives (b).

2.1.2. The two negation types under study: *not* and *un*

In this sub-section, I briefly discuss the two negation types, *not* and *un* that are the focus of the four studies in this thesis. As negation with *not* has been discussed in the previous sections, I caution that some parts of the following discussion might come across as repetitive but are nonetheless necessary in comparing the two negation types.

Negation with 'not'

As has been mentioned, the first type of negation that is the focus of this thesis is negation with *not* (also referred to as free-standing negation or sentential negation) in combination with adjectival meanings (e.g., *not happy* or *not intentional*). Negation with *not* is one of the most common expressions of negation and has long been the subject of theoretical and empirical investigations. When *not* operates on adjectival meanings such as *happy* (*not happy*) and *true* (*not true*), it takes scope over the adjective. As such, this type of negation can be considered a form of constituent negation because negation operates on the adjectival meaning within its scope. However, categorizing this negation type as only constituent negation is not enough. Negated forms such as *not happy* are of course part of a sentence and the proposition expressed by the sentence. As a matter of fact, example 3a shows that the scope of negation extends beyond the adjectival meaning and influences other parts of speech such as the verb (*is*) and licenses the adverb (*at all*). The adverb *at all* is a polarity item that can be used in non-assertive contexts such as the one created by *not*. The negator *not*, as a non-assertive form, opens up possibilities and different interpretations. This is not the case for prefixal negation with *un*. In this respect, prefixally negated forms function as assertive forms (much like their non-negated affirmative counterparts), that is, they simply reverse the scale associated with the affirmative meaning (*happy-unhappy*) (for more details on assertiveness see Quirk, Greenbaum, Leech, & Svartvik, 1985, pp. 83–86). With prefixal negation, the scope of negation remains within the dimension expressed by the adjective and the negating prefix cannot interact with other sentential constituents in the same way as sentential negation does (example 3b).

3) a. Mary is *not happy* at all

   b. *Mary is *unhappy* at all

The test with such polarity items (*at all*) indicates that the classification of prefixal negation as a form of negation should be questioned. Negation with *not* and negation with *un* often do not function in the same way. However, such purely theoretical tests (using polarity items) cannot provide enough evidence as to whether or not prefixally negated forms are indeed a form of negation. It is important to also tap into the interpretation and processing of such forms to be able to provide an adequate answer to this question. This is precisely what I have tried to address in this thesis.

Negation with 'un'

Negation with *un*, commonly referred to as prefixal negation (also known as morphological negation), refers to negated forms by means of prefixes such as *un*, *in/m/l/r*, *dis* and *de*. These negating prefixes can attach to adjectives, adverbs, nouns or verbs and create a number of different meanings. One of the most common and productive prefixes in English is *un* (Plag, 2003). This prefix can attach to verbs

(*unbutton*, *untie*) to convey the reversal of an action, and to nouns (*uncertainty*), adverbs (*unwillingly*), and adjectives (*uncertain*, *unwilling*) to convey opposition (see Plag, 2003 for more information about morphological formation and Horn 2005 for prefixal negation). In this thesis, the focus is on the combination of *un*-prefixed negation with adjectival meanings, in which case the prefix operates on the meaning dimension of the adjectival meaning and forms an opposite to the non-negated base form (e.g., *happy-unhappy* or *true-untrue*). As such, the scope of prefixal negation is limited to the meaning structure of the lexical item within its scope and hence, prefixal negation is considered to be a form of constituent negation, similar to the case of negation with *not* discussed above.

The application of negating prefixes to adjectival meanings is similar to that of *not* in the sense that prefixal negation is also sensitive to the boundedness property of adjectives and can create both non-scalar (*authorized-unauthorized*) and scalar (*happy-unhappy*) opposite pairs as depicted in Figure 2. However, the difference between negated adjectival opposites with *un* and those with *not* is when they apply to a scalar meaning, in which case the prefixally negated adjective (e.g., *unhappy*) cannot modify the scale associated with *happy* in the same way as *not happy* can. In other words, the opposite pair *happy-unhappy* is more likely to form a symmetrical scale while *happy-not happy* may not. The prefix *un* is not used to hedge utterances in the same way as *not* is (*How are you? Not bad*, which normally is understood as 'good'). This means that there is less flexibility or variation in the interpretations arising from *unhappy* compared to *not happy*. In the case of negated non-scalar adjectives with *un* and *not*, as in *unauthorized* and *not authorized*, they both refer to the side of the domain that is the opposite of *authorized*, which means that interpretations arising from *unauthorized* and *not authorized* are typically similar.

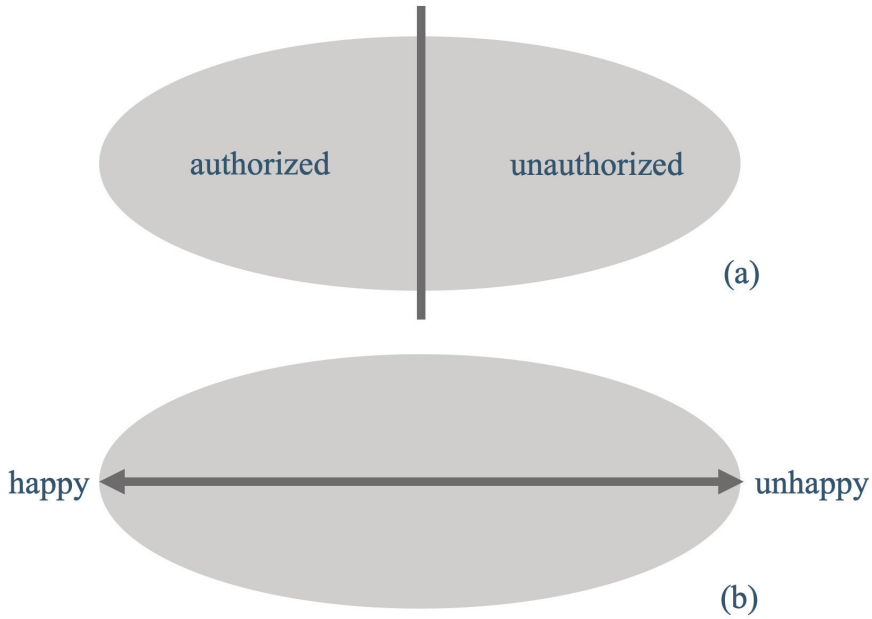


Figure 2. A configuration of prefixally negated meaning dimensions used in the four investigations in this thesis Both bounded (a) and unbounded (b) adjectives can be prefixally negated.

Traditionally, prefixally negated adjectives are considered to convey a negative, depreciatory or pejorative meaning (Cruse, 2011; Horn, 1989). However, as meaning is extremely dynamic in that it is construed in context, the negative or depreciatory treatment of prefixally negated meanings should be viewed as contextually induced. While an adjective such as *unpleasant* obviously carries a very negative meaning, the adjective *unknown* can be used in a negative or positive light depending on the context in which it is used.

2.1.3. Negation with *not* versus negation with *un*

In this sub-section, I compare negation with *not* and negation with *un* and describe the similarities and differences between them, some of which have already been mentioned in previous sections where these forms were individually discussed. I start by outlining the differences, and then move to similarities, which lay the ground for contrasting these two negation types.

The first and most obvious difference between the two expressions of negation is form. Sentential negation is expressed through a separate word (e.g., *not likely*), while prefixal negation is expressed through the use of a prefix added to a word (e.g., *unlikely*). Clearly, this can create differences in the processing of these forms,

as will be discussed in Section 2.2. These confounding factors were the motivation behind Study 1 where the meaning ranges associated with *not* and *un* were studied in a strictly-controlled artificial language learning paradigm so that frequency (exposure) and length could be controlled for (see Section 4.1 for more details).

The next difference lies in the meaning scope expressed by these two negated forms. In order to better understand and characterize the interpretive differences between the two negation forms under study, I make use of Verhagen's (2005) cognitive discursive model to illustrate how they differ (see Figure 3). According to his model, the main difference between a sententially negated expression (*not happy*) and a prefixally negated expression (*unhappy*) lies in the number of mental spaces that they evoke. With a sententially negated statement such as *not happy*, the speaker evokes two distinct mental spaces with two different epistemic stances towards the same proposition and instructs the addressee to engage in one and abandon the other (Verhagen, 2005).

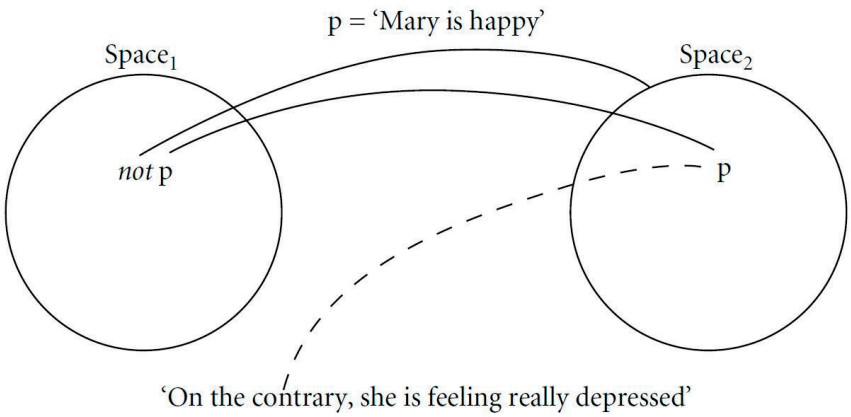


Figure 3 Configuration of the two mental spaces evoked by sentential negation (Verhagen, 2005, p. 32)

As Figure 3 illustrates, one mental space refers to the negated predicate that is evoked by the use of negation ($Space_1$: *not* p) and the other mental space refers to a pre-existing non-negated predicate that is also evoked ($Space_2$: p). When speakers use a negated sentence such as *Mary is not happy*, they create these two opposing mental spaces and instruct the addressee to engage in one (*not* p) and abandon the other (p). However, the other mental space ($Space_2$: p) is not always fully rejected but can be entertained and used in certain contexts. More specifically, Verhagen (2005) explains this phenomenon by contrasting a negated opposite (*not happy*) with a prefixally negated opposite (*unhappy*) in examples 4a (p. 31) and 4b (p. 32). The

pre-existing predicate ($Space_2$: p) in sentential negation allows for the second part of example 4a to be acceptable, while the existence of one mental space in prefixal negation makes the second part of example 4b unacceptable.

4) a) Mary is *not happy*. On the contrary, she is feeling really depressed.

   b) *Mary is a bit *unhappy*. On the contrary, she is feeling really depressed.

Verhagen's discursive-intersubjective model (2005) in Figure 3 can be contrasted with the cognitive semantic model of negated meanings (Paradis, 2005, 2008) illustrated in Figure 1. In Verhagen's model, the two mental spaces are comparable with the two parts of the meaning configuration divided by negation in the cognitive semantic model, whether this configuration is scalar or not. However, the advantage of the scalar model of negated meanings lies in: i) highlighting the type of meaning configuration that negation operates on, which in turn allows for ii) accounting for different interpretations of negation when applied to different types of configurations (scalar or non-scalar), and finally, iii) its ability to explain the flexibility in the interpretation of negated meanings that can vary across contexts where a typically bounded reading of e.g., *married* can be laid out on a scale when used in a context such as *She is very married*. With the cognitive semantic model, we can also account for other negated instances such as prefixal negation (*happy-unhappy*, *intentional-unintentional*) because both members of a prefixally negated opposite pair map on to the same meaning domain but occupy opposite poles or sides of it. This treatment of negated adjectives has been adopted in this thesis.

The other difference between sentential negation and prefixal negation, which has been discussed from a configurational point of view, is 'scope'. From a discursive point of view too, scope has been shown to be one of the most important differences between the two negated forms with *un* and *not*. In a corpus study by Tottie (1980), these two negated forms were compared and a number of differences were identified between the use of prefixal and sentential negation. Both written and spoken data were analysed for the use of sentential and prefixal negation and it was found that in only 10% of the cases, these two negation types can be replaced in context without any change in meaning. In the other 90% of the cases, switching from prefixal negation to sentential negation and vice versa would result in a change in meaning. Among the differences identified in the use of these forms, scope ranked the highest suggesting that the meaning scope associated with negated meanings varied when switching from one form to the other (Tottie, 1980). Consider example 5a from Tottie (1980, p. 106) for prefixal negation, and compare it with its constructed sententially negated version in 5b:

5) a) … and what parts ... are in fact only supported by matter which is *inconclusive* or suspect.

   b) … and what parts ... are in fact only supported by matter which is *not conclusive* or suspect.

As seen in example 5, the scope of negation may vary with prefixal negation and sentential negation. In the case of prefixal negation (5a), the scope is limited to the adjective *conclusive* while in the case of sentential negation (5b), the scope of negation is extended to *suspect*. In fact, the meaning potential may be extended to everything else but *conclusive* and *suspect*.

In spite of these differences, similarities between the two forms exist that allow for comparisons to be made. Importantly, it has been shown that in 10% of cases, negation with *not* and negation with *un* can be synonymous and interchangeably used in constructions as exemplified in 6 and 7 where the sententially negated adjective can be replaced with prefixally negated forms with little change in meaning in this particular context (Tottie, 1980, p. 120):

6) they … have a fourth category which is their answer was *incoherent*.

7) … and thus, though present, the iron is *not available* as plant food.

This restricted structure (NP-copula-Adj) is exactly what has been adopted for the construction of sentences in Studies 2–4, in order to minimize change in meaning or rather differences in interpretations (see Section 3.3.2 for more details).

Additionally, in terms of the semantics of negation types with *un* and *not*, both negated meanings can be operationalized in terms of 'lacking' the property of the meaning dimension on which they operate (e.g., AFFECT: *unhappy*, *not happy* or INTENTIONALITY: *unauthorized*, *not authorized*), as opposed to their non-negated counterparts which signify 'having' the property of the meaning dimension (e.g., AFFECT: *happy* or INTENTIONALITY: *authorized*) that the opposite pair is associated with.

2.2. Behavioural evidence on the processing of negation

Research on the processing of negation dates back to the 1960s and onwards where an extensive body of literature was dedicated to how different expressions of negation were processed and what made their processing difficult (Clark, 1969; Just & Carpenter, 1971, 1976; Clark & Chase, 1972; Glass, Holyoak, & Carla, 1974; Hoosain, 1973; Just & Clark, 1973; MacDonald & Just, 1989; Sherman, 1973, 1976; Slobin, 1966; Wason, 1959, 1961; Wason & Jones, 1963). Different proposals and

speculations were put forward as to why negation induces a processing cost, some of which will be discussed below.

The first and most common factor contributing to this effect was the extra word or syllable (negating operator such as *not*, *no*, *un*) in a negated statement as opposed to the non-negated form. However, the extra reading time associated with the extra syllable for negation *not* was previously calculated and found to account for 25 to 90 milliseconds of the difference between the processing of the negated form and the non-negated form, while the processing cost of negation could amount to several hundred milliseconds (Clark & Chase, 1972). It was also shown that the comprehension of negation took longer even in a sentence-picture verification task where the picture appeared 3 seconds after the sentence was read (Gough, 1966). This suggests that the length difference alone could not account for all of the processing difference.

The next proposal for the processing cost associated with negation was the negative connotation associated with negated words. It was reported that words with negative connotations took longer to process than words with positive connotations (Just & Clark, 1973; Wason, 1959, 1961; Wason & Jones, 1963). In one of the earliest studies on negation, Wason (1959) tested the processing of positive and negative information where he instructed the participants to complete affirmative or negative statements so that the statement either agreed or conflicted with a situation including 4 squares and 4 colour words presented in a figure (e.g., *There is/is not both yellow/green in 4 AND red/black in 3*). The results of this task revealed that the mean response time for processing the negated statements was longer than affirmative statements (Wason, 1959). Wason's explanation was that there was more interest in positive information that asserted compared to negated information that denied (1959). He argued that the emotional side of negative expressions could affect the cost that negation added to comprehension; words with positive connotations were more pleasant than words with negative connotations (Wason, 1959). In another study, Just and Clark (1973) also found evidence suggesting that in a sentence verification task, it took longer for the participants to process words such as *forget* and *thoughtless* as opposed to *remember* and *thoughtful* (Just & Clark, 1973). However, this effect was not consistently found across studies possibly because i) the evaluative polarity (negative vs. positive) of an item can be independent of negation and not all negated forms are evaluatively negative, and ii) the evaluative polarity of words is not always an inherent feature of the meaning dimension but can vary depending on the context; for example, the word *long* can be positive in one context and negative in another (Clark, 1969; Paradis, van de Weijer, Willners, & Lindgren, 2012).

The other explanation that was proposed as a source of difficulty for the processing of negation was explained by a two-step simulation model (Kaup, Lüdtke, & Zwaan,

2006). According to this model, the processing of negation involves two simulation steps. In processing a sentence such as *The door was not open*, the first step involves the simulation of the 'open door', and the second step involves the integration of negation and simulation of the 'closed door'. It is the presence of these two simulation steps, as opposed to the one step in affirmative sentences, that delays the integration of negation and causes a difficulty for processing (Kaup et al., 2006; Kaup, Yaxley, Madden, Zwaan, & Lüdtke, 2007).

The notion that negation induces a processing cost did not remain unchallenged. Studies were conducted reporting that the extra processing cost for negation could be due to an inappropriate and insufficient context where it was tested, or could be caused by the confusability and ambiguity of the context (Arroyo, 1982; Glenberg et al., 1999; Wales & Grieve, 1969; Wason, 1965). Wales and Grieve (1969) argued that the difficulty that was associated with negation was not merely caused by its nature and how it operated on statements, but it was caused by the confusability and complexity of the materials used in the previous studies and that if this confusability or complexity was decreased and controlled, the comprehension of negation would be facilitated. Arroyo (1982) further showed that context played an important role in the processing of negated forms and it could either facilitate or slow down processing. He argued that when negation properly fulfilled its role of contrasting or "distinguishing the exception from the norm" (Arroyo, 1982, p. 124) as determined by the context, processing was facilitated. Moreover, Glenberg et al. (1999) conducted two experiments, one of which tested negated sentences outside relevant context and the other tested the negated sentences within adequate context. The results showed that the processing of negated sentences was facilitated in the presence of sufficient supporting context and that negated sentences were no more difficult than their affirmative counterparts. However, the processing time was increased when negated sentences were tested outside the context.

These results show that there are multiple factors that can affect the processing difficulty of negation and it is essential to further explore the constraints that govern the processing of negated meanings by zooming in on the cognitive operations behind these negated meanings (Study 1) as well as the integration of these forms into larger discourse (Studies 2–4).

2.2.1. Processing prefixal negation

With regard to prefixal negation, only a few studies in the 1970s investigated the processing of these forms (Hoosain, 1973; Sherman, 1973, 1976). These studies have presented contrasting results as to whether or not prefixal negation adds a processing cost to comprehension (Sherman, 1976, 1973; Hoosain, 1973). Sherman (1973), in his first study, tested these negation types by means of a verification task and found that prefixally negated forms (*unquestionable, impossible, untidy*) were

more difficult to process than their non-negated counterparts (*questionable, possible, tidy*), but that they were not as difficult as negated forms with *not* (*not questionable, not possible, not tidy*). However, in a second study, he did not find such an increased processing difficulty for prefixally negated forms compared to non-negated affirmative forms (Sherman, 1976). He tested both prefixally negated and evaluatively negative words such as *unhappy* and *sad* in affirmative and multiply negated sentences such as *He had just won a lot of money in a contest, and everyone (believed/doubted) that he would (not) be (unhappy/sad) about this*. The results showed that negative words (*unhappy*, *sad*) did not significantly increase comprehension difficulty in comparison to the affirmative form (*happy*) when they were the only negative in the sentence. However, in the presence of two or more negatives (*doubt*, *not*), they increased comprehension difficulty (Sherman, 1976). Sherman (1976) argued that the processing cost associated with prefixally negated forms in the previous study was caused by the fact that many multiply negated sentences were included in the stimuli; the participants were exposed to double negation, including the prefixed form, and experienced comprehension difficulty. Thus, according to him, whenever the participants encountered the prefixed forms, they expected double negation and processed these forms for a longer time to make sure that no double negation was involved. On the other hand, when few multiply negated sentences were included in the stimuli, this difficulty was reduced. Alternatively, he proposed that prefixally negated forms were processed in two ways, either as single lexical items, or as negated items (Sherman, 1976).

Hoosain (1973) also investigated the processing of prefixal negation as part of the stimuli in a task which required the participants to verbally complete two phrases using either *but* or *and*. The stimuli consisted of sentences such as *Ben is friendly … faithful* or *Ben is unfriendly … unfaithful* or *Ben is not friendly … not faithful*. He found that prefixally negated forms were not significantly more difficult than the affirmative forms, and both of these forms were easier to process than negated forms with *not*. Considering these findings, it is still unclear whether prefixally negated forms are processed as negated expressions that induce a higher difficulty in processing, or whether they are processed as single lexical items that do not involve negation and thus are not significantly different from their non-negated forms.

2.3. Neurophysiological evidence on processing negation

Before I present the neurophysiological findings on the processing of negation, it is important to introduce the study of semantic incongruities using ERPs, which is the main method used in Studies 2–4. The purpose is to introduce the use of ERP responses and the processes reflected by these responses. I will then provide a comprehensive summary of previous research on negation using ERPs.

2.3.1. Processing semantic incongruities with ERPs

Processing semantic incongruities (also referred to as semantic anomalies or violations) has been repeatedly used as an index of language comprehension in sentence processing paradigms with ERPs. Semantic incongruity refers to a word or expression that is inconsistent with the context in which it appears, typically the preceding context. If we take the example *A robin is a X*, the word *bird* instead of *X* would result in a semantically congruent context while the word *tree* instead of *X* would create an incongruent context (Fischler, Bloom, Childers, Roucos, & Perry, 1983). The ERP responses (neurophysiological brain responses; see Section 3.2.2 for more details) to the incongruent word *tree* in relation to those to the congruent word *bird* are analysed to understand the neural mechanisms underlying the processing of these forms and more generally, different linguistic phenomena. A number of ERP responses have been identified in relation to the processing of semantic incongruities, which will be discussed below.

In one of the earliest ERP studies on language processing (Kutas & Hillyard, 1980), the processing of sentences such as *He spread the warm bread with socks/butter* was investigated. It was found that ERPs to the final-sentence words *socks* (incongruent) and *butter* (congruent) resulted in different ERP amplitudes. In particular, a larger negative-going wave peaking around 400 ms (N400 response) after the onset of the word was observed for the incongruent word *socks* compared to the congruent word *butter*. This N400 effect was taken to reflect disruption in processing and higher efforts in integrating the meaning of the incongruent word into the context. Since then, many studies have replicated this finding and have reported an N400 in connection with semantic incongruities of different sorts using stimuli in the form of words, pictures, sentences and sounds (see Kutas & Federmeier, 2011). The N400 effect has not only been found in response to incongruities that require word meaning, but also those that need world knowledge. In a study with Dutch speakers, the comprehension of sentences such as *The Dutch trains are yellow/white/sour and very crowded* was tested in which *yellow* was "semantically and pragmatically congruent", *white* was "semantically congruent but

pragmatically incongruent", and *sour* was "semantically incongruent" (Hagoort, Hald, Bastiaansen, & Petersson, 2004). The results showed a larger N400 for both semantically incongruent (*sour*) and pragmatically incongruent (*white*) compared to the semantically and pragmatically congruent (*yellow*).

There have been different views on the type of processes that the N400 can reflect. Recent studies have associated it with predictive processing in that word predictability, as measured by cloze probability, modulates the N400, that is, more predictable words elicit a smaller N400 than less predictable ones (Kutas & Federmeier, 2011). Based on this, one view of the N400 posits that this negativity reflects pre-lexical processes such as lexical access and activation. According to this view, the meaning of an upcoming word is activated based on the contextual cues prior to the word's appearance and if the word is predictable based on those contextual cues, it elicits a small N400 (Kutas & Federmeier, 2011). Another view has associated the N400 with post-lexical processes that occur after the word has appeared (Hagoort et al., 2004). According to this account, the N400 targets a later stage of processing (post word recognition) and is associated with the process of linking up or integrating the semantic information available by the word with the meaning information from the context (other words)—semantic unification. However, there have been studies arguing that the N400 does not reflect only either one of these processes but can be a combination of different processes (Baggio & Hagoort, 2011; Nieuwland et al., 2018; Lau, Namyst, Fogel, & Delgado, 2016). Accordingly, a dynamic view of the N400 as a combination of different processes has been developed (Baggio & Hagoort, 2011). Recent evidence in support of this dynamic view has shown that predictability, plausibility and semantic relatedness can all modulate the N400 response. All these effects, when controlled for, can be teased apart as indicated by the differences in onset and topographic distribution (Nieuwland et al., 2018)

Another important ERP response in relation to semantic incongruities is the P600, that is, a positive-going wave with an onset around 600 milliseconds after the onset of the incongruent word. The P600 was originally associated with anomalies of syntactic nature and garden-path sentences as repeatedly reported in many studies of the 1990s (Coulson, King, & Kutas, 1998; Friederici, Pfeifer, & Hahne, 1993; Neville et al., 1991; Osterhout & Holcomb, 1992; Osterhout, Holcomb, & Swiney, 1994). More recently, however, studies have reported a similar positivity to be elicited by violations of semantic nature (Bornkessel-Schlesewsky & Schlesewsky, 2008; Brouwer, Fitz, & Hoeks, 2012; Burkhardt, 2007; Chow & Phillips, 2013; Kolk, Chwilla, van Herten, & Oor, 2003; van Herten, Chwilla, & Kolk, 2006; van Herten, Kolk, & Chwilla, 2005). For example, in an incongruent sentence such as *The fox that hunted the poachers* [...] (Kolk et al., 2003), a P600 was observed where the reversed assignment of thematic roles (i.e., *fox* and *poachers*) could render an otherwise unacceptable reading of the sentence acceptable. The same result was

reported by van Herten et al. (2005) when they presented semantic reversal anomalies in syntactically-correct sentences such as *The cat that fled from the mice* [...]. In another study, Burkhardt (2007) investigated the processing of sentences such as *A student was shot/killed/found dead. The next morning, a jogger found the pistol behind a tree*, creating contexts with varying degrees of inferential association between the target word *pistol* and the verb in the first sentence: necessary context (*shot*), probable context (*killed*), and inducible (*found dead*). Instead of a modulation of the N400 response, she found a larger P600 for both probable and inducible contexts in comparison with the effects elicited by the necessary context. She argued that the elicitation of a P600 rather than an N400 in this study indicated that the lexical-semantic processes and discourse-level processes are qualitatively different and can affect semantic memory differently. The P600 effects observed in the probable and inducible contexts suggest an extra cost for semantic memory due to updating the mental model that was previously created before encountering the word *pistol*. Burkhardt (2007) argued that upon encountering the word, the participants were required to either introduce this instrument as "a new discourse entity" or update the information in the first part of the sentence, that is, updating *killing* to *shooting* so that it was in line with *pistol*. This process could overburden the discourse memory and lead to the P600. These results challenge the purely syntactic view of P600. Instead, based on the discussed findings, the P600 can reflect a monitoring process in which the participants, upon encountering an incongruity call the initial interpretation into question and perform a reprocessing of the sentence in order to check the veracity of the statement, or to update the mental model when encountering information that deviates from the context-based inferences.

2.3.2. Studying negation with ERPs

Studies using ERPs in the investigation of negation have been interested in the time-course of integration of negation. In one of the earliest studies, Fischler et al. (1983) investigated the processing of affirmative and negated sentences such as *A robin is (not) a bird/tree* with four truth-value conditions: true–affirmative, false–affirmative, true–negated and false–negated. The two conditions true–affirmative (*A robin is a bird*) and false–negated (*A robin is not a bird*) were semantically primed (semantic match between *robin* and *bird*) and the false–affirmative (*A robin is a tree*) and true–negated (*A robin is not a tree*) conditions were semantically unprimed (semantic mismatch between *robin* and *tree*). The ERPs to the critical words *bird* and *tree* were analysed and compared and the results showed a larger N400 for the false condition compared to true conditions in affirmative sentences (larger N400 to *tree* than *bird*). However, in negated sentences, this pattern was reversed in that a larger N400 was observed for the true condition compared to the

false condition (also larger N400 to *tree* than *bird*). In other words, the N400 effect was modulated by semantic priming, that is, the semantically unprimed conditions elicited a larger N400 than the semantically primed conditions, irrespective of negation and the truth-value of the sentence (Fischler et al., 1983). It was then concluded that in negated sentences, the "inner proposition" was processed first and in this step, the proposition was evaluated against semantic memory. For example, in the case of *A robin is not a tree*, the participants first processed *A robin is a tree* and later negated this proposition. During the first evaluation step, the semantic mismatch between *robin* and *tree* led to the larger N400 effect. Therefore, the authors argued that the N400 reflected a semantic process rather than truth-value processing (Fischler et al., 1983). In another similar ERP study, the verification of the same stimuli was tested in Japanese with Subject-Object-Verb word order (unlike Subject-Verb-Object in English) which allowed for dissociating the semantic mismatch effect on the Object and the truth-value processing on the Verb (Katamaya, Miyata, & Yagi, 1987). In line with the previous findings, they observed an N400 effect for the object in true–negated and false–affirmative sentences compared to false–negated and true–affirmative sentences, suggesting that ERPs were modulated by the semantic mismatch, that is, the absence or presence of priming effects (Katamaya et al., 1987).

More recent studies also targeted the question of integration of negation. In an attempt to test the two-step simulation model (Kaup et al., 2006; see Section 2.2), Lüdtke et al. (Lüdtke, Friederich, De Filippis, & Kaup, 2008) used a sentence–picture verification task in which participants read sentences such as *In front of the tower there is a/no ghost*, followed by the presentation of a picture that depicted either a ghost or some other object such as a lion in front of a tower. Similar to the conditions of the previous two studies, true–affirmative (*there is a ghost* followed by *a ghost*) and false–negated sentences (*there is no ghost* followed by *a ghost*) were the primed conditions, that is, the presented picture (e.g., *ghost*) was mentioned in the previous sentence, and the false–affirmative (*there is a ghost* followed by *a lion*) and true–negated (*there is no ghost* followed by *a lion*) sentences were the unprimed conditions, that is, the presented picture (e.g., *lion*) was not mentioned in the previous sentence. In order to test the time-course of the integration of negation, two time-delays of 250 ms (short) and 1500 ms (long) were used as inter-stimulus intervals (ISI) between the sentence and the presented picture. The results showed early ERP effects in the form of a larger N400 in both time-delay conditions for the unprimed conditions compared to primed conditions. This was in line with previous findings suggesting that negation was initially ignored in processing as suggested by the two-step model (Kaup et al., 2006). Importantly, in later processing (550–1000 ms after the presentation of the image), the length of the delay (short vs. long) affected the ERPs in that a larger positivity was found for negated sentences compared to affirmative sentences after the long-delay condition. The authors

argued that their results suggest that with the short-delay condition, negation had not yet been fully integrated, and hence no effect of negation was found in the later time-window (550–1000 ms). However, with the long-delay condition, the participants had time to integrate negation, and therefore, a main effect of negation showed up in the later time-window. The authors argued that these results supported the two-step model according to which, the processing of negated information involves two steps of simulation and the N400 effect for the primed conditions reflects processes associated with the first simulation step (or the non-negated core information), and the late positivity for negated sentences reflects the second step, where negation has been integrated (Lüdtke et al., 2008). However, it is important to note that in the study by Lüdtke et al., (2008), the late effect (i.e., larger positivity) that was observed with the long-delay condition was elicited by negation and not by congruency. Therefore, it is not clear whether the incongruities were in fact processed after negation was integrated.

The delay in the integration of negation was further observed in another study with negated and non-negated counterfactual statements (Ferguson et al., 2008). The processing of sentences such as "*If cats were not carnivores, they would be cheaper for owners to look after. Families could feed their cat a bowl of carrots/fish and listen to it purr happily*" was tested and ERPs to the semantically primed word *fish* and semantically unprimed word *carrot* were analysed. Corroborating the previous findings, a larger N400 was observed for the consistent but unprimed condition (*carrots*) compared to the inconsistent primed condition (*fish*), irrespective of negation (Ferguson et al., 2008). A more recent study on negation also tested the processing of two types of negated structures such as *Zebras/Ladybirds/Thoughts are (not) stripy* and *It is (not) true that zebras/ladybirds/thoughts are stripy*, creating contexts with and without world knowledge violations (*zebras*/*lady birds*) and semantic violations (*thoughts*) (Dudschig, Mackenzie, Maienborn, Kaup, & Leuthold, 2019). The N400 response to the critical word *stripy* was measured and a larger N400 was found for semantic and world knowledge incongruities suggesting that negation was ignored in both structures (Dudschig et al., 2019). Importantly, this pattern was observed even in the second structure where negation had occurred in the beginning of the sentence and the participants presumably had enough time to integrate it. Still no effect of congruency (i.e. no modulation of N400 by congruency) was found in these sentences suggesting that negation was ignored. It was argued that it is not enough to present the negator *not* in the beginning of the sentence in order to allow more processing time for the integration of negation. A full integration of negation happens after the information related to a negated expression has been presented. It was also argued that the full meaning of the sentence is not always present at the point which the N400 is measured (Dudschig et al., 2019).

The view that there is a delay in the integration of negated information was challenged by Nieuwland and Kuperberg (2008). They questioned the view that negation is more difficult to process than affirmatives considering that negation is a prevalent and frequent linguistic phenomenon in our everyday speech. They argued that the pragmatics of negation suggest that it is typically used to reject a plausible statement and hence when negation is used in contexts where it does not fulfil its natural function, it can be rendered as redundant and uninformative and can hinder processing. Alluding to this argument, using negation to reject a statement such as "*A robin is a tree*" (Fischler et al., 1983) does not fulfil its most natural function, while rejecting a statement such as "*A whale is a fish*" (Wason, 1965) is more plausible. They criticized the use of unnatural contexts for the processing of negation in previous ERP studies and advocated for a pragmatic view of negation, arguing that the integration of negation was not necessarily delayed when it was used in a natural or "pragmatically licensed" context, as opposed to an unnatural or "pragmatically unlicensed" context. They investigated the processing of these two types of contexts, that is, "licensed" and "unlicensed" contexts, which had been categorized based on naturalness ratings of the materials. In order to test the two-step model against a pragmatic view of negation, they created coherent and incoherent sentences such as "*With proper equipment, scuba-diving isn't very dangerous/safe and often good fun*" for the licensed context, and "*Bulletproof vests aren't very dangerous/safe and used worldwide for security*" for the unlicensed context. In this case, the negated word (*dangerous*) in the second sentence was not as informative as the same negated word in the first sentence. They predicted that according to the two-step model, a larger N400 should be found for false sentences compared to true sentences in the case of affirmatives while the reversed pattern should be observed for negated statements where negation was said to be initially ignored or was not integrated. On the other hand, according to the pragmatic view of negation, the negator could be readily integrated into the comprehension process in a natural context and the meaning of the sentence was evaluated against the real world. Therefore, according to this account, a larger N400 should be observed for the false sentences compared to that for the true sentences in both affirmative and negated sentences, but only in the pragmatically licensed contexts, and not the unlicensed context. In line with their predictions, larger N400s were found for the critical words in the false–affirmative and false–negated sentences compared to the true conditions in pragmatically licensed contexts. However, in the pragmatically unlicensed contexts, larger N400s were found for false–affirmative, false–negated and true–negated conditions, compared to the true–affirmative sentences. It was argued that these results suggest that that there was no extra semantic processing cost when negation was used in a pragmatically licensed context. They argued that the processing cost caused by the pragmatically unlicensed true negated sentences was associated with the fact that the given information was trivially true and it violated the pragmatic communicational principles. Therefore, false words and

uninformative true words should lead to similarly increased processing cost. These findings indicate that the plausibility of the context in which negation occurs plays an important role in the processing difficulty of these forms. However, it is important to note that negation does not always occur in plausible contexts and it does not necessarily reject a plausible statement. As discussed in Section 2.1, negation can have multiple functions from attenuating a statement to inducing irony and metaphor. Additionally, the stimuli used in Nieuwland and Kuperberg's study (2008) included different forms of negation such as copula+*not* (both contracted and non-contracted forms) and negating adverbs such as *never*, sometimes followed by adverbs such as *very*, all of which can make a less homogenous group of negating operators. These motivated me to further explore the processing of negated meanings in complex sentential contexts using a more restricted set of stimuli with the non-contracted form of negation with *not* (Studies 2–4).

Auditory processing of negated sentences

The studies reviewed so far all investigated the visual processing of negation. With regard to the auditory processing of negation, there is very little done using ERPs. Only two studies were conducted which, despite presenting valuable information, did not provide sufficient evidence for an understanding of processing negation in the auditory modality. In the first study by Herbert and Kübler (2011), the aim was to develop a paradigm using negation to test truth-value evaluation as an index of higher-order cognitive and conscious processing in healthy adults and eventually in patients with disorders of consciousness. Their goal was to test the complexity of processing negation at two levels, namely, word-level (*no summer* followed by *winter/sun*) and sentence level (*Dogs don't bark/fly*) using purely auditory stimuli. The reason for the auditory presentation of the stimuli was driven by the motivation behind developing and testing this paradigm for patients with disorders of consciousness, who often have reduced or impaired vision. The participants' task was to evaluate the stimuli in silence without any overt responses. The ERPs to the critical words (*sun/summer* in the word-level condition and *bark/fly* in the sentence-level condition) were analysed. In the word-level condition, they did not find any differences in the N400 modulation between what was categorized as "true but semantically incongruent" (*no summer* followed by *winter*) and "false but semantically congruent" (*no summer* followed by *sun*). It can be argued that this could have been due to the fact that both words *winter* and *sun* were semantically related to the word *summer* and could have been equally primed by it. Hence, no differences were observed between the conditions. In the sentence-level condition, even though the critical words were semantically either related (*bark*) or unrelated (*fly*) to the subject (*dogs*), no N400 effect was found for the semantically-related words, unlike the previous findings discussed earlier (Ferguson et al., 2008; Fischler et al., 1983; Lüdtke et al., 2008). Instead, a larger frontal negativity between 300–600 ms and a larger late positivity potential (LPP) between 600–1000 ms were

observed for false–negated sentences compared to true–negated sentences. Since these target words were presented with an ISI of 1500 ms, it can be argued that such a long ISI (or pause) between the negator (*don't*) and the target word (*bark/fly*) poses an issue for the ecological validity of the experiment. In fact, an average pause in natural spoken language has been shown to be around 300 ms (ten Bosch, Oostdijk, & Boves, 2005). Moreover, no baseline condition such as an affirmative counterpart was included in the design of the experiment in order to compare the patterns observed in the negated condition with a non-negated condition.

In a second similar study, Herbert and Kissler (2014) investigated the processing of negated sentences in two tasks: first, an implicit passive listening task with no instructions, and second, an explicit active evaluation task determining the truth-value of the same stimuli used in the first task. Their aim was to see how a passive listening task affected an active evaluation task and whether it would result in attenuated ERP effects due to repetition, or facilitate the integration of negation and lead to enhanced ERP patterns in the explicit task. Sentences similar to those used in Herbert and Kübler (2011) were used where the final word of the sentence was either semantically-related or semantically-unrelated to the subject (*dogs cannot fly/bark* or *blood is not green/red*). This time, the final target words were presented with an ISI of 500 ms. The instructions of the explicit task required half of the participants to perform the judgment task mentally and the other half by pressing buttons. The results revealed larger ERP amplitudes in the explicit task compared to the passive listening task suggesting that an active evaluation of sentences requires more resources and is more difficult than their passive evaluation. In comparing the two tasks, a larger LPP was found between 500–800 ms for false compared to true sentences in the passive listening task. This effect was reversed in the explicit task and true sentences resulted in a larger positivity in the same time-window. Moreover, a frontal negativity was elicited by true compared to false sentences in the explicit task. Overall, their results revealed that the N400 and the LPP effects are modulated by the nature of the task. A possible concern with the results in this study involves the multiple manipulations in between the two tasks. The results from the explicit task could have been driven by a number of factors such as repetition effects (the use of same stimuli), which in turn could have led the participants to have different expectations and processing strategies and could have required different amounts of working memory capacity. Additionally, the difference in instructions to the participants on how to evaluate the explicit task (mentally or by button presses) could have also contributed to the obtained results of this task. Considering the possible shortcomings of the two reviewed studies, more research is required on the auditory processing of negation using better controlled paradigms, stimuli with more natural ISIs and with the affirmative form included as a baseline condition. This is what has been targeted in Study 3.

3. Methods

This section provides an overview of the experimental paradigms, techniques, measurements, materials and participant groups that were used in the four investigations.

3.1. Paradigms

3.1.1. Study 1: Artificial language learning

In Study 1 of this thesis, I used an artificial language learning paradigm in order to study the processing of negated meanings that are similar to the interpretation of negated meanings with *un* and *not*, in a natural language such as English, in a tightly controlled setup. I will first introduce the paradigm, its strengths and weaknesses, and next, I will provide the rationale for the choice of artificial language learning.

The use of the artificial language learning paradigm dates back to the 1960s and 1970s (Braine, 1963; Glass et al., 1973; Green, 1979). Despite the rather long history of its use, the artificial language learning paradigm is not a particularly well-documented paradigm in the sense that there is not an established set of guidelines for researchers to follow. This can result in a long trial-and-error process in order to find the most efficient design for targeting the research questions under study. Typically, the paradigm is adapted to the purpose of the study and the availability of resources. Artificial language learning has primarily been used in language acquisition and typology research (Fedzechkina, Newport, & Jaeger, 2016), but it has also been extended to study other phenomena in language. Researchers use artificial language learning as a tool to gain control over the many factors that affect and complicate language learning, production or comprehension. Artificial language learning is a powerful paradigm for the elimination of complexities and frequency effects that are part and parcel of natural language and for isolating and controlling factors under study. One of the basic assumptions of the artificial language learning paradigm is that there are similarities and features shared between natural language and an artificial language, and that generalizations can be made from the results obtained in an artificial language learning task (Folia et al., 2010).

For a more comprehensive account of the artificial language learning paradigm, its application in various fields of research and its relevance for natural language, see Fedzechkina et al. (2016) and Folia et al. (2010).

Like many other paradigms, artificial language learning has its drawbacks too. One of the most common criticisms of the paradigm is its simplicity, which is also considered one of its advantages. An artificial language includes a limited number of words and these words are typically short and lack form complexity and multifunctionality. The simple reason for this is that it has to be possible for the participants to learn the language within one or a couple of sessions (Fedzechkina et al., 2016). Despite these shortcomings, there is evidence in favour of the fact that similar patterns have been found in artificial language learning and natural language learning which makes this paradigm worthwhile using (Fedzechkina et al., 2016; and Folia et al., 2010).

Study 1 in this thesis made use of artificial language learning to test the two types of negated meanings with *not* and *un*. Subtle meaning differences with varying forms and frequencies of use (*not happy* vs. *unhappy*) are not ideal to test via natural language learning tasks. In a previous eye tracking study, I investigated the processing of affirmative forms (*intentional*), negated forms with *not* (*not intentional*) and *un* (*unintentional*) as well as double negation (*not unintentional*) in a sentence processing task in a natural language (English) (Farshchi, 2013). The frequency of affirmative and negated adjectives was found to have a statistically significant effect on the regressions that were made to these adjectives, which suggested that frequency played an important role in the processing of these forms. Therefore, in this thesis, one of the main goals was to find out how these negated forms were processed when controlled for frequency and length differences. To this end, I designed two tightly controlled experiments using artificial language learning and controlled for length (by presenting all meaning types through artificial prefixes) and frequency (by presenting novel adjectives) in order to conduct a baseline study for the future research on different negated meanings (see Section 4.1 for more details).

3.1.2. Studies 2–4: Sentence processing

In Studies 2–4, the focus shifted from the processing of negated meanings at word level (Study 1), to sentence level. In order to investigate the interpretation and processing of negated forms in contexts that resembled more natural situations of language use, I made use of a sentence processing paradigm. I will first briefly introduce the sentence processing paradigm and next, discuss the rationale for the adoption of this paradigm in the three ERP studies in this thesis.

In a sentence processing paradigm, manipulations are presented in one or more sentences where participants' behavioural or neurophysiological responses to the reading of sentences are recorded and analysed. In some cases, the reading of the sentences is followed by an evaluation task mainly to ensure attention and comprehension. While in offline experiments with behavioural measurements, the follow-up question plays an important role in reflecting successful processing, in paradigms using online measurements such as eye tracking and ERPs, this is, strictly speaking, not necessary (Rommers & Federmeier, 2018). The advantage of such online methods lies in the fact that they reveal the processes underlying language comprehension in real time and hence, they render overt responses a source of additional information. However, it has also been shown that the presence of a task, the nature of the task and the follow-up question after the task can modulate the ERP responses (Herbert & Kissler, 2014; Kuperberg, 2007; Nieuwland, 2014).

The presentation of sentences in a sentence processing paradigm varies across different studies depending on the measurement techniques and research questions. For example, in one version of the paradigm, sentences are presented fully and at once. In such cases, the reading of the sentences resembles natural reading behaviour in that participants can choose to go back and re-read earlier parts of the sentence. In other paradigms, the reading behaviour is less natural. For example, in a self-paced reading (SPR) paradigm or a rapid serial visual presentation (RSVP) paradigm, the sentence is presented word by word in the centre of the screen. The presentation time of each word is determined by the participant (for SPR) or the experimenter (for RSVP). Importantly, these paradigms (SPR and RSVP) do not allow for revisiting earlier parts of the sentence requiring participants to perform processing in a unidirectional incremental manner, which may require a higher cognitive effort.

The RSVP paradigm is particularly common in ERP sentence processing research for two reasons. First of all, the word-by-word presentation of the sentences allows us to tap into the processes underlying the comprehension of each individual word. More specifically, the high temporal resolution of ERP methodology makes it possible to study the online processing of words as they unravel. Secondly and more importantly, EEG is highly sensitive to eye movement artifacts such as blinks (Luck, 2014). In natural reading, we tend to move our eyes across the screen in order to move from one word to another, and we move back and forth in text in order to ensure comprehension. This results in multiple horizontal eye movements or saccades, which show up as strong patterns that are not induced by processing per se and thus are considered artifacts in the continuous electroencephalogram. Therefore, in order to minimize the number of saccades during reading, the sentences are presented one word at a time at the same location on the screen, so that participants avoid making horizontal (and vertical) eye movements to different parts of the screen. More recently, eye tracking and ERP techniques have been

combined to allow for a more natural presentation in which the full sentence is presented at once and participants can re-visit and re-read earlier parts of the text (Henderson, Luke, Schmidt, & Richards, 2013; Kretzschmar et al., 2013; Plöchl, Ossandón, & König, 2012).

In an RSVP paradigm, using ERPs, studies have used approximately 200–400 ms presentation time per word (Burkhardt, 2007; DeLong, Quante, & Kutas, 2014; Kos, Vosse, van den Brink, & Hagoort, 2010; Lago, Namyst, Jäger, & Lau, 2019; Nieuwland, 2015, 2016; Thornhill & Van Petten, 2012), while other studies have made use of presentation times based on word length (Nieuwland & Kuperberg, 2008). Because ERP responses are highly sensitive to the presentation and processing of the preceding context and words (Luck, 2014), an ISI of 100–300 ms (Burkhardt, 2007; Chow & Phillips, 2013; DeLong et al., 2014; Kos et al., 2010; Lago et al. , 2019; Nieuwland, 2015, 2016; Thornhill & Van Petten, 2012) is typically used in between every two words in order to allow the ERP waveforms associated with the preceding word (word n-1) to return back to their normal baseline level so that they do not overlap with the induced ERP effects of the target word (word n). In Studies 2 and 4 in this thesis, the sentence processing paradigm was used in which the presentation time for each word was 300 ms and the ISI was 200 ms.

In Study 3, an auditory sentence processing paradigm was adopted to test the auditory processing of negated sentences. All stimuli sentences from Study 2 were read aloud by a native speaker of British English while being recorded in an anechoic chamber, ensuring stimuli with clear onsets. Next, the stimuli were spliced into four parts to construct the conditions under study. In order to control for confounds caused by the preceding context, two ISIs of 9 and 11 ms were respectively used before the adjectives in the first part of the sentence and the critical words in the second part. These ISIs were determined based on the average natural pause between the target words and their preceding words in the original recordings.

3.2. Measurements

3.2.1. Study 1: response time and accuracy

Response time and accuracy are both offline behavioural measurements that have been widely used in psycholinguistic research when studying various linguistic phenomena (Kaiser, 2013). Response time as a measure typically refers to the time it takes for a participant to process and provide a response to a linguistic stimulus. Response accuracy refers to whether the registered response is correct (agrees with the expected response) or incorrect (disagrees with the expected response). Both

measures are dependent variables that are taken to indicate difficulties associated with processing a stimulus and as such, longer response times and lower accuracy rates are associated with higher difficulty levels in processing (see Section 2.2 for some examples). While response time and response accuracy are well-established measures that reveal valuable information about processing, they are both offline indices presumably measuring and reflecting a combination of multiple processes completed prior to when the response was registered. Hence, the individual processes contributing to these responses cannot be teased apart.

In study 1, the main measures of analyses included response times and accuracy rates in order to identify the difficulty of processing associated with negated and non-negated meanings. In Studies 2–4, both these offline measurements were combined with the online measurements, namely, ERPs, which were more apt to provide an adequate answer to the research questions in Studies 2–4, that is, the time-course of processing negated meanings. I included both these measures for three reasons: i) to compare both behavioural and neurophysiological findings as previous ERP studies had found a dissociation between offline and online measurements, ii) to ensure comprehension (by collecting accuracy responses) as the stimuli sentences in Studies 2–4 were complicated, and iii) to make use of the behavioural results in the interpretation of the ERP studies if and when possible.

3.2.2. Studies 2–4: EEG/ERP

Electroencephalogram or EEG is a non-invasive electrophysiological technique in which the electrical activity of the brain is measured by placing electrodes on the scalp, amplifying the electrical signal and plotting the changes in voltage over time (Luck, 2014). Continuous EEG as a raw measure consists of a mix of different sources of activity and as such it is difficult to tease apart specific individual processes that are ongoing in the brain. When continuous EEG is time-locked to the onset of a specific stimulus such as a word, picture or sound, and is averaged over many trials, we can investigate the event-related potential (ERP) responses to that specific stimulus. The averaged ERP waveforms consist of a series of positive and negative deflections or responses which are seen in Figure 4 (taken from Study 2). Different quantitative aspects of these waveforms can be analysed. For instance, differences in *amplitude* and *latency* of ERP responses can reflect speed and difficulty of processing, and differences in *polarity* and *topography* of the responses can reflect qualitatively different processes.

Traditionally, negative voltages have been plotted upward and positive voltages downward in ERP research. Even though this counterintuitive plotting convention is changing, many studies, including the studies in this thesis, continue with the upward plotting of negative voltages. The naming convention of the ERP effects follows from the negative or positive going waves. For example, the ERP effect

N400 refers to a negative-going waveform (hence N) which typically peaks around 400 ms after the onset of the stimulus, and the P600 component refers to a positive-going wave (hence P) with an onset around 600 ms after the onset of the stimulus, exemplified in Figure 4. These negativity and positivity deflections do not need to be negative or positive in absolute terms; rather, they are typically compared cross-conditionally and the negativity or positivity is determined in relation to other conditions (Luck, 2014).

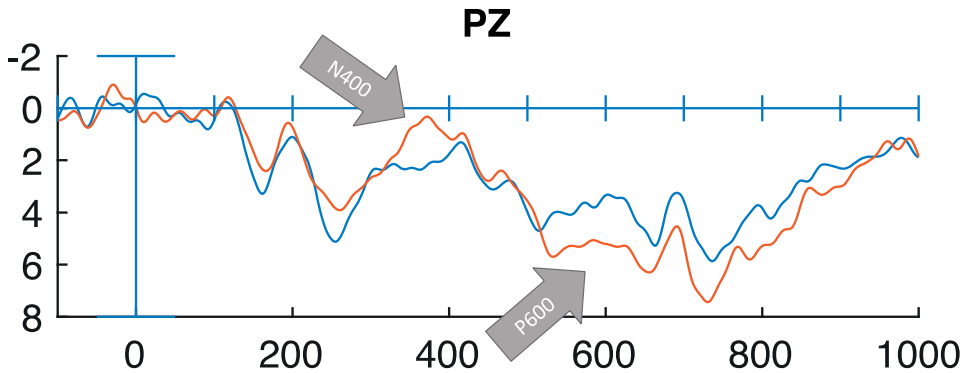


Figure 4. The ERP waveforms from Study 2 indicate the N400 and P600 effects Averaged ERP waveforms for congruent (blue) and incongruent (red) conditions in a sentence processing task. Semantic incongruities elicited a larger N400 followed by a larger P600 in affirmative sentences.

The most important aspect of ERP methodology is the extremely high temporal resolution of this technique, which allows for monitoring the ongoing processes as they unfold down to milliseconds (Luck, 2014). This is a valuable property of this technique for targeting questions about the detailed time-course of processing stimuli. This was in fact the motivation for the adoption of this method in Studies 2–4 in this thesis. The research questions in all three ERP studies (see Table 1 in Section 1.1) target the processing of negation in sentential contexts and hence, it is important to investigate the time-course of the integration of negated meanings using an online technique, namely, ERPs.

ERP responses in language research

Many ERP responses have been identified to be associated with language-related processes (see Swaab, Ledoux, Camblin, & Boudewyn, 2012). In this sub-section, I will focus on two responses that are widely-used in language processing, namely, the N400 and the P600, and will briefly describe the processes reflected by these responses. Both these responses are central to the ERP studies in this thesis and have been used in investigating semantic incongruities in different types of stimuli (e.g., words, pictures, sounds and sentences) (see Section 2.3.1).

Firstly, the N400 refers to a negativity that is typically present between 200–600 ms after stimulus onset and is largest over centro-parietal sites, often with a slightly right-hemispheric bias (Kutas & Federmeier, 2011). While all words elicit an N400, this effect was first discovered in 1980 when Kutas and Hillyard presented participants with sentences with congruent or incongruent endings as in *I take my coffee with sugar and cream/dog* and they found that the incongruent word (*dog*) elicited a larger negativity around 400 ms (Kutas & Hillyard, 1980) compared to the congruent word (*cream*). Since then, many other studies have provided evidence for this negativity in relation to semantically meaningless or incongruent stimuli (see Kutas & Federmeier, 2011). At the word-level, the N400 is sensitive to semantic relatedness, frequency, familiarity, etc. (Kutas, 1993; Van Petten, 1993). The N400 is not exclusive to linguistic phenomena. Studies using picture–sound verification tasks have also reported a larger N400 for the incongruent stimuli (Dudschig et al., 2018), which suggests that the N400 response has gone beyond the linguistic paradigm and has been shown to index a broader range of processes that involve meaning processing, and not exclusively language processing.

Secondly, the P600 effect is a positivity that typically onsets between 600 to 800 ms after the onset of a target word and is largest over the parietal regions (Osterhout & Holcomb, 1992). This effect was traditionally associated with anomalies of syntactic nature, as discussed in Section 2.3.1. However, recent research has found a similar positivity to be associated with violations of semantic nature and to reflect re-evaluation of the content of the sentence (Bornkessel-Schlesewsky & Schlesewsky, 2008; Brouwer, Fitz, & Hoeks, 2012; Burkhardt, 2007; Chow & Phillips, 2013; Kolk et al, 2003; van Herten et al., 2006).

Since Studies 2–4 in this thesis deal with incongruities of a semantic nature, the time-windows associated with these effects, N400 and P600, are investigated in order to look for any differences between the processing of affirmative and negated forms as measured by ERPs. A third ERP effect, namely, late positivity potential (LPP) is also investigated in Study 3, which is based on the previous literature (Herbert & Kissler, 2014; Herbert & Kübler, 2011), and can show an overall increased difficulty in processing.

Experimental procedures and data processing

In this sub-section, a brief description of the experimental procedures and data processing used in Studies 2–4 will be presented for the readers who are unfamiliar with the technique.

A typical ERP experimental session started with the participant's signing a consent form. Next, two electrodes were placed on the mastoid bones behind the ears, which were taken as the reference point for the rest of the electrodes. Mastoid bones are typically chosen because they pick up very little brain activity or muscle noise. Two

facial electrodes were then placed next to the eyes to identify the horizontal eye movements, and two were placed above and below the left eye to identify vertical eye movements. Next, all these electrodes were filled with gel that functioned as a conductor and helped create a connection between the electrodes and the skin. An electrode cap was then placed on the participant's head and was measured so that it was centred on the head. All the electrodes attached to the cap were filled with gel to create connection with the scalp. The impedance levels were maintained below 5 kΩ for all scalp and mastoid electrodes and below 15 kΩ for the facial electrodes. The EEG channels were online referenced to the left mastoid and EEG was recorded at either 500 Hz (Studies 2 and 3) or 1000 Hz (Study 4), in which case it was later down-sampled to 500 Hz. After data collection, the processing of the data was performed using EEGLAB (Delorme & Makeig, 2004) and ERPLab (Lopez-Calderon & Luck, 2014). The continuous EEG was offline filtered at 0.01 Hz. Next, manual artificial rejection was performed and only excessive muscle noise (EMG) was removed. The data was then filtered with a low-pass filter of 40 Hz and was referenced to the average of the two mastoids. Next, Independent Component Analysis (ICA; runica routine of EEGLab) was used and components corresponding with eye movements were identified and removed. The identification of these components was based on extensive visual inspection of continuous EEG channels and continuous ICA components as well as the ICA component maps. The data was then segmented into epochs from 100 ms prior to the target word until 1000 ms after the onset of the target word. The epoched data was inspected once more and any trials with remaining artifacts were removed.

3.3. Stimuli

Below I will present a description of the steps and criteria involved in selecting and construction the stimuli in all four studies.

3.3.1. Study 1

As outlined in Section 2.1, in study 1, I made use of scalar adjectives (e.g., *old-young*, *happy-sad*) to be able to manipulate the meaning ranges associated with negated meanings (e.g., *not old-unold, not happy-unhappy*) while keeping the form constant (by means of an artificial language learning paradigm). This was because when a non-scalar meaning such as *true* is negated either by a prefix as in *untrue*, or the negator *not* as in *not true*, similar interpretations tend to arise, in this case 'false'. However, when a scalar meaning such as *happy* is negated as in *not happy*, a range of interpretations along the affect scale are possible, except for the range expressed by *happy*. When comparing a scalar meaning negated by *not* as in *not*

happy with that negated by *un* as in *unhappy*, the scopal range for the meaning of prefixal negation (*unhappy*) is narrower (than that of *not*) and involves a reversal of the scale in the same way as *sad* does (see Figure 1 in Section 2.1.1). The interpretation of *not happy*, on the other hand, can be broader in that it can be the complete opposite of *happy* and thereby overlap with *unhappy*, or it can apply to different ranges on the scale except for the range which *happy* covers. This characteristic of negated scalar meanings allowed me to manipulate and test the scalar ranges associated with the two negated forms (*not* and *un*) in two experiments in Study 1.

3.3.2. Studies 2–4

In Studies 2–4, in order to keep the two negated forms (*not* and *un*) as comparable as possible and to keep the interpretive differences arising from these negated forms to the minimum in sentences in natural language (English), I made use of negated non-scalar meanings (unlike Study 1). This was because when a non-scalar meaning such as *intentional* is negated by the negator *not* or *un* as in *not intentional* and *unintentional,* the interpretations that arise from these two negated forms are similar and they both refer to the same part of the opposing domain, that is, the opposite of *intentional*.

In the creation of the stimulus sentences, I used 17-18 non-scalar adjective sets, extracted from the Corpus of Contemporary American English (COCA) (Davies, 2008-). These adjective pairs came from three frequency ranges where: i) the base form was more frequent than the prefixed form, ii) the base form was less frequent than the prefixed form, and iii) the base form was approximately as frequent as the prefixed form. This way, all possible frequency ranges between the two forms were used. For each adjective set, three sentence frames (i.e., contexts) were created that used the same pair of opposites in the creation of the incongruities . For the creation of the sentence frames, the adjectives were searched for in the COCA corpus in order to make sure I found co-occurring nouns and suitable contexts. A total of six native speakers of English (from different varieties) were consulted in order to ensure the naturalness of the sentences.

3.4. Participants

3.4.1. Study 1

In Study 1, a total of 74 participants with Swedish as their native/first language were recruited and participated in two experiments. Most participants were monolinguals, some were bilingual or multilingual. The rationale for choosing Swedish speakers was: i) the use of an artificial language learning task, which allowed for testing any group of participants with a homogenous language background, and 2) the resemblance between the Swedish language and English, in particular, in the use of negating words and prefixes, which allowed for comparisons to be made between the processing of these negation types by Swedish speakers and English speakers.

3.4.2. Studies 2–4

In Studies 2–4, a total of 91 participants with English as their native/first language were recruited. In Studies 2 and 3, which were conducted in Lund, Sweden, the participants were monolingual, bilingual or multilingual with English as their first or dominant language. In Study 4, which was conducted in Ottawa, Canada, all participants were monolingual speakers of English and were born and raised in Canada.

4. The investigations

4.1. Study 1

In two artificial language learning experiments, the first study in this thesis targets the processing of negated meanings with *not* and *un* and the cognitive operations involved in the processing of these meanings. Previous studies comparing prefixal negation (*unhappy*) with non-negated affirmative forms (*happy*) and free-standing negation (*not happy*) have reported inconclusive results. Some have reported that prefixally-negated words are more difficult to process than affirmative words (Sherman, 1973), while others have not found a higher processing cost for prefixal negation compared to affirmatives (Hoosain, 1973; Sherman, 1976) (see Section 2.2.1 for more details). The first goal here is to find out whether or not the equivalent of prefixally negated meanings in natural language are processed in the same way as non-negated meanings or as negated meanings. In order to make a claim about prefixed forms as a type of negation, it was important to include an expression of negation that was comparable to prefixal negation and had previously been found to be more difficult than both affirmative forms and prefixed forms. To this end, free-standing negation with *not* was included as a point of reference as it has been reported that this negation type (*not*) induces a greater processing difficulty than both affirmative forms (Clark, 1969; Just & Carpenter, 1971; MacDonald & Just, 1989; Wason, 1959, 1961) and prefixed forms (Hoosain, 1973; Sherman, 1973, 1976). However, comparing affirmatives with negated forms with *un* and *not* in a natural language such as English entails frequency and length differences. In order to circumvent such confounding factors that affect the processing of these forms in natural language, I carried out two artificial language learning experiments and presented three meaning types through artificial prefixes: *ka* ('un'), *va* ('not') and *sa* (empty prefix for affirmatives). By controlling for forms (all prefixes), I was able to test the meaning ranges (scope) associated with these negated meanings. However, this manipulation required the use of meanings that could be laid out on a scale in the scope of negation. This is because different interpretations can be evoked between the scalar adjectives negated by *not* or by *un* (*not happy, unhappy*), but this is not necessarily the case with negated non-scalar adjectives (e.g., *not true*, *untrue*) (see Section 2.1.1 for more details). Therefore, the three artificial prefixes were combined with artificial scalar adjectives (*prab* = 'happy') to form a negated or non-negated item (*saprab* = 'happy', *kaprab* = 'unhappy' and *vaprab* = 'not

happy'). The processing of the combined forms was then explored in a picture–word verification task where meaning ranges and their interpretations were manipulated and tested. As both negated forms were represented by artificial prefixes in this study, they were referred to as "broad negation" for negation with *not* and "narrow negation" for negation with *un*, motivated by the scopal ranges of these forms. Three research questions were at the heart of this study: 1) Is narrow negation processed in the same way as non-negated words? 2) Is broad negation more costly to process than narrow negation? and 3) Does manipulating the meaning scope of broad negation affect its processing difficulty? If so, in what way?

In Experiment 1, the scope of broad negation overlapped with the scope of narrow negation as depicted in Figure 5. The experiment consisted of three phases: 1. Training phase of artificial prefixes (negated meanings), 2. Training phase of new artificial adjectives and 3. Testing phase using a picture–word verification task. In the first phase, the participants learnt the meanings of the three prefixes *sa*, *ka* and *va* through word and picture associations. Next, they learnt eight scalar artificial adjectives. In the last phase, the learnt prefixes were combined with the new adjectives and the processing of these forms was tested. The results showed that narrow negation was more costly to process compared to its non-negated counterpart. However, this cost was not as high as broad negation. The greater processing difficulty of broad negation is in line with the previous studies that reported a greater processing difficulty for negation with *not* than negation with *un* (Hoosain, 1973, Sherman, 1973, 1976) and non-negated meanings (Just & Clark, 1973; Wason, 1959, 1961). The new finding from this experiment is that the processing of the meaning scope associated with prefixal negation (narrow negation) is more difficult than the processing of non-negated meanings, contrary to the previous findings (Hoosain, 1973; Sherman, 1976).

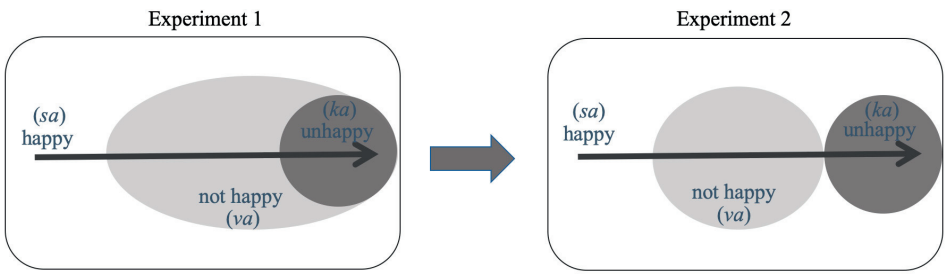


Figure 5. The manipulation of the meaning scopes associated with negated meanings in Experiment 1 and Experiment 2

In Experiment 2, the scopal range expressed by broad negation was restricted, and its application was limited to a middle range as depicted in Figure 5. This manipulation was based on the findings suggesting that in most cases, when a scalar meaning is negated, the interpretations arising from such negated instances apply to a middle range on a scale rather than the opposite end of the scale (Giora, Fein, Ganzi, Alkeslassy Levi, & Sabah, 2005b; Giora et al., 2007; Paradis & Willners, 2006, 2013). The results of this manipulation showed that the difference between narrow and broad negation that was found in Experiment 1 was no longer present in Experiment 2. This suggests that when the meaning range of *not* was limited to an intermediate range on a scale and it did not overlap with that of *un*, it was no longer more difficult for the participants to process this meaning range (*not happy*) compared to the other two meaning ranges (*unhappy* and *happy*). Additionally, no differences were found between the processing of narrow negation and the non-negated condition. The results of Experiment 2 are in line with the findings of the perception of intermediates showing that identifying an intermediate range on a scale is not necessarily more difficult than identifying either poles of the scale (Bianchi, Burro, Torquati, & Savardi, 2013).

The overall results from Study 1 show that processing the meaning scope expressed by prefixal negation (narrow negation) is more difficult than processing the meaning scope expressed by non-negated meanings when frequency and length are controlled for. However, this difficulty is not as high as processing the meaning scope expressed by free-standing negation with *not* (broad negation) (Experiment 1). It is further shown that the processing difficulty of these forms is sensitive to the meaning scope or scalar range expressed by these forms. When the scope is restricted and non-overlapping with narrow negation (Experiment 2), the processing difficulty of negated meanings decreases. Extending these results to natural language use (Fedzechkina et al., 2016; Folia et al., 2010), these scopal ranges can be determined and modulated by the context in which negated meanings occur and consequently affect the processing cost of these meanings.

4.2. Study 2

In Study 2, I move from the processing of negated meanings at the level of individual form–meaning combinations (Study 1) to processing at a higher level, that is, sentence processing using ERPs. This is to test the processing of negated meanings in sentential contexts that resemble everyday communication in e.g., news media outlets. The use of an online methodology such as ERPs allows for a detailed analysis of the time-course of processing negated meanings in real time. Previous ERP findings on negation have not been in line with each other. Negation has previously been studied in sentential contexts such as *A robin is not a bird/tree* and

been found to be ignored in initial processing as suggested by the larger N400 effect elicited by the congruent word *tree* compared to the incongruent word *bird* (Fischler et al., 1983). In other words, it has been found that the incongruent negated sentence (*A robin is not a bird*) does not elicit a larger N400 compared to the congruent negated sentence (*A robin is not a tree*). These findings have been explained by two different views on negation: 1. The two-step simulation model (Kaup et al., 2006; Lüdtke et al., 2008), and 2. The pragmatic view of negation (Nieuwland & Kuperberg, 2008). Based on the two-step simulation model, the processing of a negated sentence such as *The door is not open* involves two representations or steps: in the first step, negation is ignored and the non-negated state is simulated, that is, 'the open door', and in the second step, negation is integrated and the negated state is simulated, that is, 'the closed door' (Kaup et al., 2006). According to this view, the elicitation of the larger N400 in response to the word *tree* than the N400 to the word *bird* in *A robin is not a tree/bird* (Fischler et al., 1983) reflects the first simulation step (i.e., *A robin is a tree*) where there is a mismatch between *robin* and *tree*. However, the pragmatic view of negation (Nieuwland & Kuperberg, 2008) maintains that the reason why negation is not integrated and the incongruity is not processed is because of the unnatural and implausible context in which negation occurs. Based on this explanation, Nieuwland and Kuperberg (2008) have shown that negation is not more difficult to process than affirmatives if it is used in a plausible context where negation has been used to reject a plausible statement (see Section 2.3.2 for more details). Despite these valuable findings, more research is required to explore the processing of negated meanings in various contexts. This prompted me to revisit the issue of integration of negation in complex sentential contexts. Additionally, as previous research on prefixally negated forms is scarce, these forms were also included in order to find out whether they were processed similarly to negated forms or to non-negated forms. I ask the following questions: 1) Does sentential negation cause any difficulty for comprehension (e.g., delay in integration), or is it processed similarly to the affirmative forms, as reflected by ERPs? and 2) Is prefixal negation (*un*) processed similarly to sentential negation (*not*) or to the affirmative form?

In a sentence comprehension task, the processing of the two negated types, namely, sentential negation (*not intentional*) and prefixal negation (*unintentional*) was compared with the processing of the non-negated affirmative form (*intentional*), which was taken as a baseline condition. The participants were presented with sentences such as *The White House announced that the new Obama biography was authorized/unauthorized/not authorized therefore the details in the book were* ***correct/wrong*** *in actual fact*, in which the first part contained the negated or non-negated adjective (underlined) and the second part contained one member of an opposite pair (bold), depending on which, the meaning of the sentence was either congruent or incongruent. The sentences were presented word-by-word on the

screen with a presentation time of 300 ms per word and an ISI of 200 ms. The participants' task was to answer the question "Did the sentence make sense, logically?". The ERPs were time-locked to the opposite pair (critical word) and amplitudes for the N400 response (300–400 ms) as well as the P600 response (450–600 ms) were analysed. Additionally, accuracy responses and response times to the judgements of the sentences were also collected and analysed.

The overall results showed that the two types of negation were more costly to process than affirmatives with the unexpected finding that prefixal negation led to an even greater processing difficulty than sentential negation. More specifically, the behavioural results showed lower accuracy rates for prefixal negation compared to sentential negation and affirmative forms. No differences were observed in the behavioural results between sentential negation and affirmative forms, which suggests that the incongruities in sententially negated sentences were eventually processed in a similar way to those in affirmative sentences. Importantly, however, the ERP patterns revealed different mechanisms underlying the processing of all three forms. First of all, for affirmative sentences, we replicated the previous studies on semantic incongruities (Fischler et al., 1983; Kutas & Hillyard, 1980) and observed a larger N400 effect for the incongruent than the congruent conditions, which reflected that the incongruities were successfully detected. This N400 was followed by a P600 effect, which indicated re-analysis and re-evaluation of the content of the sentence as suggested by previous studies of semantic incongruities (Brouwer et al., 2012; Kolk et al., 2003; Kuperberg, 2007; van Herten et al., 2006; van Herten et al., 2005). For negated sentences, however, different patterns emerged. In prefixally negated sentences, the incongruities elicited a sustained anterior negativity. This anterior negativity was taken to reflect a higher demand on working memory as suggested by the previous studies that reported similar anterior negativities (Martín-Loeches, Muñoz, Casado, Melcón, & Fernández-Frías, 2005; Müller, King, & Kutas, 1997). It was argued that when the participants encountered the prefixally negated words (*unauthorized*) in the first part of the sentence, they might have treated these forms as a unit rather than an explicitly negated form (i.e., *un* + *authorized*). Next, when they encountered the incongruity in the second part of the sentence, they presumably had to retrieve the negated meaning from memory in order to repair the incongruity. However, because the negated meaning was not processed as an explicitly negated form, the recalling process taxed working memory, which resulted in the anterior negativity. This, combined with the lower accuracy rates for prefixal negation, suggests that prefixally negated sentences were the most difficult condition to process. In sententially negated sentences, both congruent and incongruent words elicited a large N400. The equally large N400 responses for both congruent and incongruent conditions may suggest that the contexts in which negation (*not*) occurred was not predictable enough and hence the participants encountered a difficulty with the integration of both congruent and

incongruent words, a finding that has previously been reported by Nieuwland and Kuperberg (2008). Additionally, the incongruities in sententially negated sentences elicited a prolonged negativity (450–600 ms) over the central region. This negativity was taken to reflect the detection of incongruities, but with a delay and a greater processing difficulty. This negativity was also deemed to reflect memory processes behind the retrieval of the negated meaning, similarly to the argument about taxed working memory processes for prefixal negation.

The findings in Study 2 suggest that the processing of sententially negated sentences are more difficult than affirmative sentences as reflected by the prolonged negativity in response to the incongruities. Even though a greater processing difficulty is observed for sentential negation, the results do not provide evidence for the first step of the two-step model (Lüdtke et al., 2008). Additionally, these results are not in line with the pragmatic view of negation either (Nieuwland & Kuperberg, 2008) as differences were observed between the processing of sententially negated and affirmative sentences. However, it is important to note that the results of this study are not directly comparable with those by Nieuwland and Kuperberg (2008) as the materials in this study are not pre-tested for plausibility. Overall, the results suggest that not all instances of negation can be explained by the two views discussed above. The processing of negation is very complex and more research is required to unravel the different factors that affect the processing of negated meanings in various contexts. With regard to prefixal negation, the results indicate that the retrieval of prefixally negated forms is a costly process for working memory and these forms induce a greater processing difficulty than that for affirmative forms and even sententially negated forms.

4.3. Study 3

In Study 3, the processing of affirmative and negated sentences is investigated in the auditory modality. Previous research (Fischler et al., 2008; Lüdtke et al., 2008; Nieuwland & Kuperberg, 2008) on the processing of negated forms has been inconclusive as to whether or not negated information is integrated with a delay and hence affect ERP effects such as the N400 (see Section 2.3.2 for more details). Additionally, most of this research has relied on the use of visual stimuli, while little has been done on auditory processing of these forms despite the pervasiveness of this mode of processing in our daily lives. Only two studies (Herbert & Kissler, 2014; Herbert & Kübler, 2011) have been conducted in the auditory modality in which the processing of negated sentences such as *Dogs don't bark/fly* was investigated using ERPs. No N400 was elicited by incongruent sentences in either studies. Instead, a late positive potential (LPP) was found in response to the incongruities in negated sentences. Considering a number of limitations (discussed

in Section 2.3.2) and the scarcity of research on auditory processing of negation, I target the issue of processing negated sentences in the auditory modality in this study asking the following questions: 1. Is there a difficulty in the auditory processing of negated sentences as reflected by ERPs? and 2. Is there a difference between the auditory and visual (Study 2) processing of affirmative and negated sentences?

The same stimuli as in Study 2 were auditorily recorded and presented to the participants. The same setup, procedure and analysis as in Study 2 were performed. The ERP responses to the critical words, response time and response accuracy to the judgements of the sentences were collected and analysed. In addition to analysing two time-windows for the detection of the N400 (450–650 ms) and P600 (650–800 ms) response, a third time-window was also analysed in order to capture the LPP (800–1000 ms) as had previously been found in auditory studies on negation (Herbert & Kissler, 2014; Herbert & Kübler, 2011).

The overall results suggest that the prefixally negated forms were more difficult to process, followed by sententially negated forms and affirmative forms. More specifically, the behavioural results showed lower accuracy rates for prefixal negation and sentential negation compared to the affirmative forms within the congruent condition. The ERP results revealed a larger N400–P600 response elicited by the incongruities in affirmative sentences reflecting the detection of the incongruities (N400) followed by re-analysis processes (P600). For sententially negated sentences, the incongruities elicited a larger P600, significant over the anterior region, suggestive of reanalysis processes. In prefixally negated sentences, no P600 was observed in the selected time-window but a larger positivity was found for the incongruities in the time-window of LPP, which was taken to be a P600 with a longer latency (800–1000 ms) than the P600 effects observed in affirmative and sententially negated sentences. These results are similar to those found in the previous auditory studies (Herbert & Kissler, 2014; Herbert & Kübler, 2011), where a late positive potential was observed in response to incongruent negated sentences. The lack of an N400 effect in response to incongruities in sententially negated sentences suggests a higher processing cost for these forms compared to affirmative sentences, and the positivity with the longer onset for prefixally negated sentences suggests that this condition was the most difficult to process.

In comparing these results with the visual study (Study 2), the patterns for affirmative sentences are replicated (N400–P600). For both negated sentences, clearer patterns associated with easier processing are observed in the auditory paradigm compared to the visual paradigm. In the visual study (Study 2), a sustained anterior negativity as well as a negativity over the central region were observed, both of which are not established effects elicited by semantic incongruities. In the auditory paradigm, however, the ERP effects observed (P600) have previously been

found in studies on the processing of semantic incongruities (Herbert & Kissler, 2014; Herbert & Kübler, 2011; Kolk et al., 2003; Kuperberg, 2007; van Herten et al., 2006; van Herten et al., 2005). Therefore, it can be concluded that the auditory processing of negated sentences is easier than visual processing using a word-by-word presentation paradigm (Study 2).

4.4. Study 4

Study 4 of this dissertation is yet another visual ERP experiment that manipulates the order of the presentation of negated forms in sentential contexts. In Study 2, the negated or non-negated adjective was presented in the first part of the sentence, while a pair of opposites in the second part (critical word) rendered the sentence as congruent or incongruent (see Section 4.2). In that sense, when the participants encountered the critical word (i.e., a member of the opposite pair), they probably had to tap into memory and recall the negated meaning that they had encountered earlier in order to determine the congruency of the sentence. The results of Study 2 showed that this recalling process was costly as it led to negativity effects that could be interpreted to reflect taxed working memory processes. In this study, I switch the order of the presentation of negated and non-negated adjectives in context and present participants with sentences such as *The details in the new Obama biography were correct/wrong because the book was* ***authorized/unauthorized/****not* ***authorized*** *by the White House*. With this manipulation, the relevance of the negated information instantly becomes clear upon presentation (i.e., the presented negated information determines the congruency of the sentence). At the same time, the immediacy of the negated information in context is also manipulated (i.e., negation is fresh in memory and can easily be accessed). Immediacy in this study refers to the time in between the presentation of the negated meaning and the point at which the relevance of this information becomes clear and the negated meaning can be accessed to process the congruency of the sentence. The research question addressed in this study is: Does manipulating the relevance of the negated information in context (i.e., negation is presented at a point when the congruency of the sentence becomes clear) and hence the immediacy of negation (i.e., the negated meaning is fresh in memory and can easily be accessed) facilitate its processing?

The sentences were visually presented with the same presentation time (300 ms) and ISI (200 ms) as in Study 2. The participants' task was to answer the question "Did the sentence make sense, logically?" after each sentence. The ERPs were time-locked to the critical word that was the negated or non-negated adjective (bold) in the second part of the sentence. In sententially negated sentences (*not authorized*), the ERPs were time-locked to the onset of the adjective (*authorized*). In addition to ERP responses, behavioural responses (response time and accuracy) to the sentences

were also collected and analysed. The same data processing procedure and analyses as in Study 2 were performed. Similar to Study 2, two time-windows were analysed in order to capture the N400 (300–500 ms) and P600 (500–700 ms) effects.

The overall results from both behavioural and ERP patterns showed that sententially negated sentences were the most difficult to process. The analyses of the ERP data revealed congruency effects in the form of N400 effects for affirmative and prefixally negated sentences and a P600 effect for sententially negated sentences. The behavioural results revealed longer response times and lower accuracy rates for sententially negated sentences compared to the other two forms, and no differences between affirmative and prefixally negated forms. These patterns suggest that affirmative and prefixally negated forms were processed similarly, while sententially negated forms induced a higher processing cost. In fact, in sententially negated sentences, both congruent and incongruent conditions elicited a large N400, which resulted in the lack of an N400 effect for congruency. This suggests that the processing of negated sentences with *not* was more demanding than the processing of the two other sentence types, and that the contexts created by this type of negation were not predictable enough. Therefore, the participants encountered a greater difficulty integrating the negated adjective in both the congruent and incongruent conditions (*not* ***authorized*** with *wrong/correct*).

In comparing the results from this study with those from Study 2, we observe a facilitation effect in the processing of all three sentence types. In Study 2, incongruities in affirmative sentences elicited an N400–P600 effect, while in this study, the congruency effect was limited to an N400 effect. If we take the P600 to reflect monitoring and re-evaluation processes (Bornkessel-Schlesewsky & Schlesewsky, 2008; Brouwer et al., 2012; Burkhardt, 2007; Chow & Phillips, 2013; Kolk et al., 2003; van Herten et al., 2006; van Herten et al., 2005), we can conclude that the processing of incongruities in the current study was easier than the processing of those in Study 2 as no re-evaluation was required in the current study. In processing sententially negated sentences, too, an easier processing is observed in this study compared to Study 2. Incongruities in sententially negated sentences in Study 2 resulted in a prolonged negativity effect over the central region, which is not a common effect in response to semantic incongruities. However, in this study, the incongruities elicited a P600 effect, which has previously been reported in response to incongruities of semantic nature. The facilitation effect observed in this study is even greater in the case of prefixally negated sentences. In Study 2, incongruities elicited a large anterior negativity, which is taken to reflect taxed working memory processes (Martín-Loeches et al., 2005; Müller et al., 1997). This enhanced anterior negativity is not a commonly reported effect in response to semantic incongruities and, hence, was taken to reflect a higher processing cost than both affirmative and sententially negated sentences. With the manipulation in this study, however, the processing of the incongruities in prefixally negated sentences

is facilitated as reflected by the N400 effect. I argue that the facilitation effect observed in this study is caused by the manipulation of the relevance and immediacy of the presented negated information in context. In other words, the processing of negation is facilitated, when the negated information is presented at a point when the relevance of this information in relation to the context is clear and negation can be easily accessed to determine the congruency of the sentence.

5. Discussion

5.1. Summary of principal findings

In this thesis, I set out to investigate the processing of two negated forms, *un* and *not*, and compare them to the processing of the corresponding non-negated, affirmative forms. The investigation comprises four studies. In two experiments in Study 1, I address the processing and scope of all three meanings under strict conditions using a miniature artificial language in order to avoid factors such as frequency and word length differences inherent to natural language use. The results of this study show that the mental operations behind the processing of prefixally negated meanings are more costly than those involved in the processing of non-negated meanings in this artificial language. More specifically, it is shown that when the scopal ranges of negated forms with *un* and *not* overlap (Experiment 1), the processing of negation with *not* is more difficult than negation with *un*. This manipulation, that is, the overlap between the scopal ranges expressed by *not* and *un*, resembles the interpretation of these meanings in natural language use. Therefore, the results of Experiment 1 are comparable with the findings in natural language studies suggesting a greater processing difficulty for *not* than *un* and non-negated meanings (Clark, 1969; Just & Carpenter, 1971; MacDonald & Just, 1989; Wason, 1959, 1961). Importantly, it is also shown that the processing of the scopal range expressed by *un* (narrow negation) is more difficult than the processing of the non-negated form. If this finding can be extended to natural language (Fedzechkina et al., 2016: Folia et al., 2010), it can be argued that the processing of prefixally negated meanings is more difficult than non-negated meanings when these forms are controlled for frequency and length, a finding that is not in line with those by Hoosain (1973) and Sherman (1976). Furthermore, when the scopal ranges of the two negated forms are restricted and do not overlap (Experiment 2), which might not be the most common interpretation of negation in natural language, the difficulty of processing the two negated forms decreases. If we extend these results to natural language use, it can be argued that the cost of processing negation is highly sensitive to the changes in the scope of meaning of these forms, which may vary depending on the contexts in which negation occurs in natural communication. Even though the negated forms in this miniature artificial language do not exactly resemble natural expressions of negation (e.g., the meaning of *not* expressed through a prefix), the basic operations behind the processing of these meanings resemble the mental

operations that are involved in the processing and interpretation of negated meanings in natural language. As such, this study can set a baseline for predictions and interpretations of future studies of negated meanings with mental operations that are similar to those tested in this study.

In two visual and one auditory experiments, Studies 2–4 target the processing and integration of negated meanings in sentential contexts using ERPs, as seen in Table 3. In each example, the underlined words indicate the manipulations and the adjectives in bold indicated the critical words, to which ERPs were time-locked. The ERP and behavioural patterns observed in the three studies are summarised in Table 4.

Table 3. Sample stimuli sentences used in Studies 2–4

Study	Stimuli sentence
Studies 2–3	*The White House announced that the new Obama biography was authorized/unauthorized/not authorized therefore the details in the book were **correct/wrong** in actual fact*
Study 4	*The details in the new Obama biography were correct/wrong because the book was **authorized/unauthorized**/not **authorized** by the White House*

Table 4. Summary of the ERP and behavioural patterns observed in the three sentence types in Studies 2–4

Study	ERP patterns elicited by the incongruities			Behavioural patterns
	Affirmatives	Sentential negation	Prefixal negation	
Study 2	*N400–P600*	*Central negativity*	*Anterior negativity*	*Affirmative = Sentential < Prefixal*
Study 3	*N400–P600*	*P600*	*Late P600*	*Affirmative < Sentential = Prefixal*
Study 4	*N400*	*P600*	*N400*	*Affirmative = Prefixal < Sentential*

The first important finding is the presence of an N400 effect in all three studies in response to the incongruities in affirmative sentences, which has repeatedly been reported in the previous literature (Kutas & Federmeier, 2011; Kutas & Hillyard, 1980). As affirmative sentences were included as a baseline control condition, this finding is particularly important to validate the manipulations and stimuli used in the three investigations (Studies 2–4). Even though the N400 effect is associated with the greater difficulty involved in integrating the incongruent information into the sentential meaning, in Studies 2–4, it has been taken to reflect the successful detection of incongruities. In addition to the N400, incongruities in affirmative sentences elicit a P600 response in Studies 2–3, but not in Study 4. The presence of a P600, in addition to the N400, can be taken as an indication of extra difficulty in processing semantic incongruities as this positivity has been argued to reflect re-

analysis processes (Bornkessel-Schlesewsky & Schlesewsky, 2008; Brouwer et al., 2012; Burkhardt, 2007; Chow & Phillips, 2013; Kolk et al., 2003; van Herten et al., 2006; van Herten et al., 2005). In line with this view of P600, the presence of an N400 effect only, as compared to an N400–P600 effect, suggests that the processing of incongruities in affirmative sentences is easier in Study 4, where the presentation of the information is switched compared to Studies 2–3. In fact, this facilitation in Study 4 is observed for the two negated forms, prefixal negation and sentential negation, as well. This will be further elaborated below.

In Study 2, the negated forms are presented in the first part of the sentence and the incongruities in the second part (see Table 3). In order to determine the congruency of the sentence when encountering the incongruity, the participants are likely to have to tap into memory and recall the negated meanings that they have encountered earlier. The results from Study 2, in which the participants were visually presented with the sentences in a word-by-word presentation paradigm, show that incongruities in the both negated sentences are detected, as reflected by the difference in ERP patterns. However, the ERP responses observed (central and anterior negativity effects) are not established effects associated with processing of semantic incongruities. Instead, similar negativities, in particular anterior negativities, have been associated with taxed working memory processes (Martín-Loeches et al., 2005; Müller et al., 1997). This suggests a higher processing cost for the negated forms, which could have been caused by the complicated nature of the sentences combined with the demanding experimental paradigm consisting of a word-by-word reading of sentences. This observation was the motivation for conducting Studies 3–4.

In Study 3, the processing of the same negated sentences is tested in the auditory modality, which is a more common way of receiving language input than the visual word-by-word setup used in Study 2. The results of this manipulation reveal clearer effects (P600), that is, effects that have previously been found in response to incongruities of a semantic nature (Bornkessel-Schlesewsky & Schlesewsky, 2008; Brouwer et al., 2012; Burkhardt, 2007; Chow & Phillips, 2013; Kolk et al., 2003; van Herten et al., 2006; van Herten et al., 2005). Even though no N400 is observed in response to the incongruities in negated sentences in Study 3, the presence of a P600 is an improvement compared to the unexpected effects observed in Study 2.

Study 4 is another follow-up on the findings of Study 2 where the issue of taxed memory processes was targeted and the order of the presentation of negation is manipulated. In Study 4, the order of the two clauses in the stimuli sentences (Table 3) was swapped such that the negated information, upon presentation, completes the meaning of the sentence (its relevance instantly becomes clear) and at the same time, the negated information is still fresh in memory and can be easily accessed (immediacy of negated information) to process the congruency of the sentence.

Similar to Study 3, a facilitation effect is observed in Study 4. Clearer ERP effects are observed in response to the incongruities in the negated sentences with *not* as reflected by the P600 effect, suggesting that the processing of negated meanings is facilitated when they are presented at a point when their relevance is clear and they are fresh in memory and can easily be accessed, compared to their retrieval from earlier context (Study 2).

An important point of discussion based on the findings of the three ERP investigations is the processing of incongruities in sententially negated sentences. In none of the three studies do we observe that incongruities elicit an N400 effect. First, I will discuss what might have caused this lack of an N400 effect. In Study 2, the lack of an N400 effect could have been caused by the equally large N400 responses elicited by the incongruent as well as the congruent condition. This finding has previously been reported by Nieuwland and Kuperberg (2008) in sentences with low plausibility ratings, which suggests that the participants experience difficulty integrating the incoming information, regardless of congruency. In Study 3, however, we do not observe a larger N400 response for the critical words (congruent or incongruent) in sententially negated sentences. In other words, neither of the critical words elicit a larger N400 (compared to the critical words in the affirmative condition or compared to each other). It can be argued that the processing of the critical words (e.g., *correct/wrong*) in sententially negated sentences was easier in Study 3, which was in the auditory modality, compared to their processing in Study 2, which was in visual modality using a word-by-word presentation paradigm. Similar to Study 2, the critical words in Study 4, that were now the negated adjective (*not* ***authorized***) in both congruent and incongruent conditions, resulted in equally large N400 responses. This could have led to the lack of an N400 effect for congruency in sententially negated sentences and suggests that the participants experience difficulty in integrating *not authorized* in both congruent and incongruent contexts. Even though the setup and the critical words in Study 2 and Study 4 were different, it may be argued that the mode of presentation, namely, the word-by-word visual presentation of such long sentences is one point of comparison between the two studies, which could have contributed to the greater processing difficulty associated with sententially negated forms (as opposed to their auditory processing, which is more natural). Another source of difficulty in processing sententially negated sentences and the lack of an N400 effect in such sentences—particularly in Study 3 where neither congruent nor incongruent conditions elicit a large N400—is the type of contexts that are created by sentential negation. In sententially negated sentences, the goal of the negated adjective, *not authorized*, is to evoke the opposite of the adjective *authorized*. However, as discussed in Section 2.1, negation can be interpreted in different ways in different contexts. It is likely that the interpretation of the negated adjective *not authorized* is not the absolute opposite of *authorized*. Instead, negation (*not*) can open up a range

of possible meanings and result in a mitigated reading of *authorized*. Therefore, the incongruent word in combination with the negated context (e.g., *not authorized* and *wrong* in Study 3) might not have created a strong incongruency that would lead to an N400. In other words, the context created by sentential negation (*not authorized*) might not have been predictable enough for the participant to build expectations that would later be invalidated by the incongruent word (*wrong*)—Note that I am not making any claims about the different theories on the N400 (see Section 2.3.1) and take the N400 response as a general index of processing difficulty with the integration of information into the semantic context.

Now if we consider the studies where the processing of sentential negation was facilitated, namely, in Study 3 and Study 4, we observe that the incongruities in the sententially negated sentences elicit a P600 effect. This may suggest that the mechanisms underlying the processing of incongruities in negated sentences (with *not*) are different from those in affirmative sentences (where incongruities elicit an N400 effect). The incongruities in sententially negated sentences lead to re-evaluation and monitoring processes (as reflected by the P600), which are processes that target higher discourse level mechanisms rather than the word-level mechanisms.

Another interesting finding in Study 4 involves the processing of prefixally negated forms. The results from Studies 2–3 show that the processing of prefixally negated meanings is hindered (sustained anterior negativity) or costly (late P600) as suggested by the ERP patterns and behavioural results. In fact, these results suggest that prefixal negation is even more difficult than sentential negation. In Study 4, however, incongruities in prefixally negated sentences elicit an N400 effect, which, together with the behavioural results (no differences between affirmatives and prefixal negation), suggest that the processing of these forms is greatly facilitated and these forms are no longer the most difficult condition to process. In other words, when prefixally negated meanings are presented at a point when they can be immediately accessed to determine the congruency of the sentence, they are processed similarly to their non-negated affirmative forms. However, when these forms occur in earlier context and need to be retrieved from memory in order to determine the congruency of the sentence, participants experience a greater processing difficulty. Here I will present a tentative explanation for this processing difficulty associated with prefixally negated forms in Studies 2–3.

As Table 3 shows, the prefixally negated forms occur in the first part of the sentence in the stimuli used in Studies 2–3. When participants first encounter these negated forms such as *unauthorized*, *unintentional*, *unlawful*, they might treat and process them as units or single lexical items without decomposing the word and registering the prefix *un* as a separate negator. Later on in processing, when the incongruities appear and a re-evaluation of the content of the sentence is necessary, it is difficult

for the participants to tap into working memory and retrieve the negated prefixed form and its meaning, and this causes a higher processing cost for these forms. This failure of retrieval and re-evaluation is also present in the behavioural results in both studies. The greater processing difficulty of prefixal negation in Studies 2–3 that presumably is associated with taxed working memory processes is not observed in Study 4 where the prefixally negated meaning is fresh in memory. In fact, in Study 4, prefixally negated words are processed similarly to affirmative forms without any extra difficulty. This is a finding that is in line with the behavioural studies by Hoosain (1973) and Sherman (1976) where no extra processing difficulty was observed in the processing of prefixally negated forms compared to their non-negated affirmatives.

In relation to the two accounts of processing negation, namely, the two-step model (Lüdtke et al., 2008) and the pragmatic view (Nieuwland & Kuperberg, 2008), the results of Studies 2–4 are not entirely in line with either of the views. First of all, we do not observe any evidence for the two-step model and in particular, the first simulation step (Lüdtke et al., 2008). In studies where evidence has been provided for the two-step model (Ferguson et al., 2008; Fischler et al, 1983; Lüdtke et al., 2008), the congruent negated conditions elicited a larger N400 compared to the incongruent negated conditions. For instance, in processing the sentence *A robin is not a tree/bird*, the negated congruent word *tree* elicited a larger N400 than the negated incongruent word *bird* while negation was ignored (see Section 2.3.2 for more details). In Studies 2–4, however, this effect has not been observed. Therefore, it can be argued that the processing of the negated sentences in Studies 2–4 cannot be explained by the two-step model (Lüdtke et al., 2008). The pragmatic view of negation (Nieuwland & Kuperberg, 2008), on the other hand, can better explain a part of the obtained results. First of all, it is important to acknowledge that Studies 2–4 in this dissertation are not directly comparable with the study by Nieuwland and Kuperberg (2008). This is because the predictions of the pragmatic view mainly rely on the plausibility of the context in which negation occurs. However, the stimuli sentences used in the three ERP investigations in this dissertation are not pre-tested for this plausibility aspect. Therefore, it is difficult to make strong claims about the pragmatic view of negation in relation to the obtained results. A tentative discussion, however, has been conducted regarding the type of contexts that are created by negation with *not* and the unpredictability of such contexts that may have led to the lack of an N400 effect. Therefore, the pragmatic view of negation that highlights the plausibility of the context may explain the lack of an N400 effect in the incongruent sententially negated contexts. However, beyond the pragmatic view of negation, the investigations in this dissertation contribute new knowledge about the processing of sentential negation in two ways: i) factors such as the mode of presentation (auditory or visual word-by-word), the relevance and the immediacy of negated information modulate the processing of negated meanings in context, and

ii) incongruities in negated sentences elicit a P600 effect that reflects monitoring and re-evaluation processes (Studies 3–4).

5.2. Revisiting the main research questions

Research Question 1 (RQ1) asked "Does negation incur a processing difficulty? If yes, in what way?". The short answer to this question is yes it does. As shown in Studies 1–4, negation has been found to be more difficult than its non-negated counterpart. This has been tested both outside the context doing away with all the confounding factors (e.g., frequency and length) and in more natural contexts involving integration and discourse processes. However, it has also been shown that the processing difficulty of negation can be modulated based on the scopal ranges expressed through negated meanings (Experiment 1 in Study 1).

The second part of RQ1 brings us to Research Question 2 (RQ2), namely "How is the processing of negated meanings modulated under highly controlled conditions (Study 1) and in the presence of a larger context (Studies 2–4)?". The answer to this question has been discussed at length above (Section 5.1). It has been shown that the processing difficulty of negation, under strict conditions, is modulated by the scopal ranges that are evoked by negated meanings (Study 1). It has further been discussed that the auditory presentation of negated sentences (Study 3) facilitates their processing compared to their visual word-by-word presentation (Study 2). Additionally, the results obtained show that the processing of negated meanings is facilitated when negation is presented at a point when its relevance in context becomes clear and the negated meaning is fresh in memory and can easily be accessed to determine the congruency of the sentence (Study 4), as compared to when the negated meaning needs to be retrieved from memory to determine the congruency of the sentence (Study 2).

Finally, Research Question 3 (RQ3) asked "What is the status of prefixally negated forms? Are they processed as a form of negation or not?". The point of departure for categorizing prefixally negated forms as a form of negation was whether the processing of these forms involved difficulties in comparison to the processing of non-negated forms. The findings of the four investigations with regard to the processing of prefixally negated meanings suggest that the answer is anything but simple. First of all, in Study 1, we observe that the processing difficulty of these meanings in relation to their affirmative counterparts varies depending on the scopal ranges that they cover. Additionally, in Studies 2–3, where the prefixally negated forms are presented in the first part of the sentence and need to be retrieved from memory for the evaluation of the congruency of the sentence, they involve a higher processing cost. However, when they are presented at a point when they can easily

be accessed for processing, they do not incur any extra processing cost. From a theoretical perspective, the function of prefixally negated words resembles a very restricted use of negation with *not* in very strict contexts, that is, opposition or scale reversal. Therefore, if we take negation to express opposition, prefixally negated words can be categorized as a form of negation. However, it is important to acknowledge that prefixally negated words simply resemble one function of negation and are vastly different from the point of view of other properties as has been discussed in Section 2.1.3. From a processing perspective, it has been shown in Studies 1–3 that the processing of these forms can more or less resemble both negated forms and thus involve a higher processing cost (Experiment 1 in Study 1 and Studies 2–3) or affirmative forms without any additional processing cost (Experiment 2 in Study 1 and Study 4). The processing cost of prefixal negation has been shown to be caused by the mental operation of opposition (Study 1) or by contextual factors such as naturalness and memory processes (Studies 2–3). More research is required to compare this negating prefix with other non-negating prefixes in order to determine whether there is more to the mental operations behind the processing of negating prefixes compared to those behnid the processing of other types of prefixes.

6. Contributions and future directions

6.1. Contributions

This thesis has investigated the processing of two negated meanings as expressed by *not* and *un* in natural language (English) from two rather different perspectives and as such, has made a number of empirical, theoretical and methodological contributions to a better understanding of negation as a cognitive and linguistic phenomenon.

One of the most important contributions of this thesis is the evidence in support of the flexibility of meaning and the role of context in the interpretation and processing of negated meanings, in line with the semantic model of meaning making (LOC, Paradis, 2005). This has been shown both at the word level (Study 1) and context level (Studies 2–4). It has been shown that the processing of negated meanings is not only modulated by the properties of the domain on which negation operates (Study 1), but also the contextual factors that go beyond this meaning domain (Studies 2–4). Study 1 has shown that the processing of the two negated forms are sensitive to their scopal properties, that is, the meaning ranges covered by these forms. Moving beyond this, Studies 2–4 have addressed the interplay between the scopal properties of negated adjectives and aspects that the context brings into the scene. The findings of this piece of research add new knowledge to the already existing view of processing as a dynamic phenomenon where, for instance, plausibility and naturalness properties of the context affect the comprehension of negated meanings (Nieuwland & Kuperberg, 2008). More specifically, this thesis shows that a number of other contextual factors, namely, sensory modality, order of presentation, relevance of information with respect to the bigger context, and immediacy of information all affect the processing of negated meanings.

Another important contribution of this thesis is the insight concerned with the treatment and processing of prefixally negated meanings. By directly comparing prefixally negated meanings with non-negated meanings as a baseline, and with negated meanings using *not*, a balanced (yet not perfect) setup was created for the investigation of these forms. It has been discussed that prefixal negation, similarly to negation with *not*, also involves the setting up of a binary construal (opposition). As such, the prefix *un* also operates on the meaning dimension of the lexical item it combines with and thereby creates a boundary between the negated meaning (e.g.,

unhappy) and the lexical item within its scope (*happy*). However, the potential negated meaning application created by the prefix *un* is more limited than that by the negator *not* (*not happy*). This is reflected in the scopal ranges expressed by these forms. It has been shown that these scopal ranges can vary and as such, affect the processing of negated meanings. Moving beyond the meaning properties at the word level, the processing of prefixal negation has also been investigated in larger context and new observations have been made suggestive of the different discursive factors (modality of the sensory input, order of presentation, relevance and immediacy) that can radically modulate the processing of these forms. These are valuable findings that have addressed the knowledge gap in the processing of prefixal negation in the literature.

Yet another contribution of this thesis lies in the type of stimuli sentences in which negated meanings were tested. Many previous investigations have tested the processing of negation in short stimuli sentences (e.g., Fischler et al., 1983; Lüdtke et al., 2008) or sentences were there is a strong priming mechanism involved (cf., Ferguson et al., 2008). More research is required for a better understanding of the processing of negated meanings in sentential contexts that are more complex (e.g., Nieuwland & Kuperberg, 2008) or in contexts where negation does not necessarily reject a plausible statement but may be used to attenuate a statement. Studies 2–4 have targeted this aspect and investigated the processing of negated and non-negated meanings in complex contexts that may be said to resemble sentences that we encounter on a daily basis in e.g., news media outlets.

Finally, an important methodological contribution of this dissertation is the replication of findings over the three ERP studies, using comparable stimuli and setups. In particular, the affirmative sentences, as the baseline condition, have produced consistent ERP patterns over Studies 2–4, which can be taken to validate the manipulations across these studies and can suggest that the different ERP patterns that have been observed in the non-baseline conditions (prefixal negation and sentential negation) across the studies could have been elicited by the manipulations.

6.2. Future directions

In this sub-section, I discuss the possibilities of the future work that can follow up on the findings as well as the limitations of the four studies in this dissertation. Unavoidably, these possibilities will address the weaknesses and shed more light on the topic at hand, that is, the processing of negation. I will start with Study 1 and will then move on to Studies 2–4.

Future work following from Study 1 may include exploiting the artificial language learning paradigm that has been developed in order to target the different formal and cognitive aspects of processing negation. First of all, in the two experiments in Study 1, the equivalent of negated meanings expressed by *not* and *un* were both expressed through prefixes (e.g., *kaprab* and *vaprab*) to keep the form constant. Presenting the meaning of the negated meaning *not* through a prefix might not be very natural and in fact, I was not able to find a language that expresses negation with *not* through a prefix. Therefore, in order to be able to corroborate the findings of Study 1 and to make stronger generalizations, it is important to also present both meaning types through separate words (e.g., *ka prab* and *va prab*), which would resemble the more natural presentation of negation with *not* in natural language. Future work could also consider counter-balancing the prefixes that are used to express the different meanings in order to avoid any biases. Additionally, other participant groups with different linguistic backgrounds can be tested in order to make sure that the obtained effects are not limited to one specific group, namely participants with Swedish as their first language.

With regards to Studies 2–4, many possibilities arise that can be further explored. Most of these include the inclusion of secondary cognitive tasks and measures. First of all, in order to directly test the pragmatic view of negation (Nieuwland & Kuperberg, 2008) and make stronger claims with regards to it, it is important to pre-test the materials for plausibility. This information can be used to gain a better picture of the materials or can be used in the statistical modelling of the ERP data. It could also be valuable to have a measure of semantic similarity between the (non-)negated adjectives and the antonym pair (e.g., *authorized-unauthorized* and *correct-wrong* or *paid-unpaid* and *allowed-prohibited*) used in the creation of the stimuli. This information could potentially help draw stronger conclusions with regards to the two-step simulation model (Lüdtke et al., 2008). More specifically, what I have in mind is that there might have been a strong semantic priming mechanism in the materials used in the studies that provided evidence in support of the two-step (Ferguson et al., 2008; Fischler et al., 1983; Lüdtke et al., 2008). By having a measure of semantic relatedness for the items used in Studies 2–4, I would have been able to make stronger claims about the fact that the results in those studies were possibly driven by priming mechanisms, and it could be the case that negation was ignored in the presence of strong priming mechanisms. Similar to plausibility ratings, the information about semantic relatedness could also be used in the statistical modelling of the data. Directly related to the two points above, it is important to be able to account for the item information in the statistical modelling of the data and for that to happen, the ERP experiment needs to be set up so that item information for every trial can be extracted and used in the statistical analyses.

In addition to the two measures discussed above, another possible addition could be the inclusion of working memory scores and investigating the role of working

memory capacity in the processing of negated meanings. Previous research has shown that working memory capacity can affect the processing of sentences as reflected in both behavioural measures (Pérez, Paolieri, Macizo, & Bajo, 2014) and ERPs (Müller et al., 1997; Münte, Schiltz, & Kutas, 1998). In Study 2, I discuss the possible role of working memory capacity in the processing of negated sentences based on the elicited ERP patterns, namely, the enhanced anterior and central negativities. In fact, with the manipulation in Study 4, I tested the processing of negated meanings when they were fresh in memory and found a facilitation effect compared to their processing in Study 2. It would, therefore, be valuable to further explore, whether and to what extent, working memory capacity can account for the ERP effects that have been obtained. In line with the role of working memory, it is certainly worth manipulating (systematically) the distance between the presentation of the negated information and the point at which the relevance or significance of this information becomes clear, in order to see whether this can affect the processing and integration of negated information in sentential contexts. This touches on the previous research on the accessibility of negated information in context (Giora, Fein, Acshkenazi, & Alkabets-Zlozover, 2007; Hasson & Glucksberg, 2006; Kaup et al., 2006; Lüdtke et al., 2008).

Another path for future work that could follow up on the findings of Studies 1–4 concerns the processing of prefixally negated meanings. As previous research on the processing of prefixally negated forms is scarce, the scope of the conclusions and generalizations made based on the findings of the four studies is limited. More work is certainly required to contribute to a better understanding of the mechanisms underlying the processing of prefixal negation. As reflected in RQ3 (Section 1.1), one of the main themes of this dissertation has been to explore the nature of prefixally negated forms and to determine whether these forms are processed as a form of negation or as affirmatives. In all four studies, prefixal negation (*un*) was compared with a non-negated affirmative condition as well as an established negated condition (*not*). The main criterion for the categorization of prefixal negation as a form of negation was taken to be the difficulty of processing these forms as compared to affirmative forms. In other words, if prefixally negated forms incurred a greater processing difficulty compared to affirmative forms, they were taken to be processed as a negated form. However, this categorical treatment of these forms may not paint a fair and complete picture. In order to gain a better understanding of prefixally negated forms, it is important to compare the processing of these forms with other prefixed forms using non-negating prefixes such as *re* (*redo, reload, re-infect* etc.) where they could be compared with prefixally negated forms using, for instance, verbal prefixes as in (*undo*, *unload*, *disinfect*). This way, we can compare and contrast the cost of the cognitive operations behind the processing of prefixal negation with the cost behind the processing of other prefixed forms such as *re*. It might be the case that the processing difficulty of a negated

prefixed form such as *undone* is the same as that of *redone* and this processing difficulty is not enough evidence for the treatment of prefixally negated forms as a form of negation. However, investigating the processing of prefixally negated forms with other prefixed forms that are comparable is quite challenging and it might require a less homogenous set of test items that would include all types of prefixally negated forms, using both adjectival prefixes (e.g., *un/il/im/ir/...*) and verbal prefixes (e.g., *un/dis/de*).

Another valuable direction for follow-up work on prefixally negated words could be the comparison of prefixally negated and sententially negated opposites (*happy-unhappy-not happy*) with lexical opposites (*sad*). While this has previously been done in short stimuli sentences (Sherman, 1976), it is important to investigate the processing of these forms in larger sentences such as the ones used in Studies 2–4 where other contextual factors are in play. By directly comparing these forms, we can find out whether the lexical equivalent of prefixal negation will also lead to similar processing patterns as the prefixed form or whether it will be processed as affirmative forms.

Overall, more research is required to investigate the processing of negated meanings in the context of larger discourse and how different encyclopaedic and discursive factors affect the processing of these forms. It deserves to be pointed out that the investigation of such phenomena in larger text can benefit from a more natural visual presentation rather than the word-by-word presentation paradigm that does not resemble natural reading behaviour. Therefore, it can be valuable to combine eye tracking and ERP techniques in order to increase the ecological validity of the experimental paradigms that use ERPs.

Yet another possible path to follow up on the findings of Studies 2–4 is to better explore the processes reflected by the N400 and P600 effects observed in the studies. In this dissertation, these two ERP responses were taken as rough indexes in that they were used as proxies for the difficulty of processing of the negated forms in comparison to the processing of the affirmative form. The processes underlying these responses were neither targeted nor discussed in Studies 2–4. It should be valuable to target the processes behind the obtained ERP effects in more detail and to be able to see how these effects can be modulated by different contextual factors such as plausibility or by working memory capacity of participants.

Finally, an extremely important and valuable follow-up could be the investigation of the research questions in other less-studied languages in order to look for cross-linguistic similarities and differences. This will allow us to get a better picture of negation in natural language processing.

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