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Negation in Context:
Electrophysiological and Behavioral Investigations of Negation Effects in Discourse Processing

A dissertation submitted in partial satisfaction of the requirements for the degree
Doctor of Philosophy

in

Language and Communicative Disorders

by

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The Dissertation of Jenny Staab is approved, and it is acceptable in quality and form for publication on microfilm:

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Staab, J. (2002). On the role of the anterior superior temporal lobe in language processing: hints from functional neuroimaging studies. *CRL Newsletter, 14(3)*, 3-14.

Staab, J., Pourcher, E., Blanchet, P., Chouinard, S., & Cohen, H. (2003). Picture naming latencies in Parkinson's disease. *Brain and Cognition, 53(2)*, 116.

Kutas, M., Federmeier, K. D., Staab, J., & Kluender, R. (2007). Language. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson (Ed.), *Handbook of Psychophysiology* (3rd ed., pp. 555-580), New York: Cambridge University Press.

ABSTRACT OF THE DISSERTATION

Negation in Context:
Electrophysiological and Behavioral Investigations of Negation Effects in Discourse Processing

by

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Doctor of Philosophy in Language and Communicative Disorders

University of California, San Diego, 2007
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Negation has been found to affect the processing of sentences and words principally in two ways: It makes sentences harder to process, increasing response times and error rates. In addition, it reduces the activation of concepts to which it applies by directing attention away from them to some non-negated alternative. Both types of effects are typically tested after the offset of the sentence.

The question addressed in this dissertation is whether negation also has effects within the same sentence, namely on the prediction of upcoming lexical items. This type of incremental processing has been demonstrated for a number of linguistic cues. A previous study of negation effects on the processing of words in the same sentence, however, failed to produce such effects. We attribute this to the fact that in the isolated sentences used in that experiment, negation actually did not change the plausibility of the sentence endings.

In order to make negation-induced expectation changes detectable, we therefore embedded affirmative and negative sentences in contexts designed to make the plausibility of a continuation dependent on the sentence mode (affirmative vs. negative). We carried out two series of experiments, differing in the structure of the discourse context. In the first set of experiments, it was the appropriate continuation of the affirmative target sentence that was directly primed, and in the second set it was the correct completion of the negative target sentence. The first experiment of each set used the event-related potential (ERP) methodology, and used the N400 to the sentence-final word as the main index of expectancy. The N400 results showed that negation can affect expectancies about sentence continuations. They also demonstrated that prediction changes are less likely when the most plausible continuation for the negative sentence is itself a negated concept and therefore subject to suppression. The ERP studies were complemented by verification experiments, differing in the way the target sentence was presented (word-by-word vs. whole-sentence). The comparison of verification times showed that negation-induced expectation changes may only occur if readers have enough time and processing capacity available.

CHAPTER 1

NEGATION IN NATURAL LANGUAGE

1.1 Introduction and Overview

In the language of propositional logic, negation is a simple concept. It is an operator that, applied to a statement, reverses the statement's truth-value: if *A* is true, then *not-A* is false and vice versa. Apart from this difference in truth-value, affirmative and negative propositions are essentially equivalent. Both are subject to the same laws of inference, are combined with the same elements and expressions. Negation within natural language usage, by contrast, is far from simple. Its effects go beyond a change in truth-value, as negative sentences are semantically, syntactically, and pragmatically different from, and arguably more complex than affirmative statements.

There is only one negation operator in logic, and it can be attached iteratively. Two negations cancel each other out, as the truth value is simply switched back and forth. So the expression *not-not-A* is equivalent to *A*. In natural language, negation can be expressed by a variety of words, such as *not* (He did *not* leave.) or *no* (I have *no* doubt.), or even prefixes like *un-* (*un*happy) or *in-* (*in*distinct). When two of these negation markers are applied to the same statement, the truth conditions for the affirmative (1) and the doubly negated version (2) may be the same, but there is a subtle change in meaning. The double negation signals a lower commitment to the truth of the statement and may attenuate its force (Horn, 1989). So negation affects meaning at more levels than just truth.

(1) Laura said that it was possible that she failed the class.

(2) Laura said that it was *not im*possible that she failed the class.

It appears that there is a considerable difference between the negative operator in propositional logic and negation in natural language. Nevertheless, important features of negation in propositional logic have been applied to the analysis of linguistic negation and the processing of negative sentences. It has been suggested that negation is mentally represented as an external operator or an embedding proposition that changes the truth of the embedded proposition (Carpenter & Just, 1975; Clark & Chase, 1972; Trabasso, Rollins, & Shaughnessy, 1971). So a negative sentence like (3) would be represented as an affirmative proposition embedded in the *not*-proposition (4).

(3) A robin is not a bird.

(4) (*not*(*robin is a bird*))

In order to comprehend such a negative sentence, a listener or reader would have to first process the embedded proposition and then apply the negation to it. So despite its sentence-medial position, negation would be integrated only after the last element of the embedded proposition has been processed. In the example (3), the processing of negation would thus be delayed until after the end of the sentence.

A delayed processing of negation seems to conflict with our intuition, as we don't have the impression that we consider the negated information to be true initially, and start to perceive it as false only upon reaching the end of the sentence or phrase. More importantly, however, it would be at odds with the evidence in favor of incremental language processing. Psycholinguistic research has demonstrated that different types of linguistic information are used as soon as they become available (Altmann & Kamide, 1999; Crocker & Brants, 2000;

Kamide, Altmann, & Haywood, 2003; Van Berkum, Koornneef, Otten, & Nieuwland, 2007), and it is not obvious why negation should be an exception.

A number of studies, however, have found empirical support for a delayed processing of negation. The most direct evidence came from a study that used event-related potentials (ERPs) to test whether negation affected the fit of a word in a sentence (Fischler, Bloom, Childers, Roucos, & Perry, 1983). The authors took the absence of such effects to suggest that negation functions as an external operator, which is processed only after the embedded proposition has been dealt with. Alternatively, it can be argued that the lack of early negation effects was due to the materials employed in the experiment, specifically the use of isolated sentences. Negation is typically used to deny the corresponding affirmative proposition, which acts as a supposition or background assumption (Strawson, 1952). It is thus a highly contextually dependent phenomenon, as context is the main source of the suppositions to be denied. Contextual factors have also proven useful in explaining processing effects associated with negation (Wason, 1971). Controlling the discourse context may thus be instrumental in producing or delaying negation effects.

The research presented in this dissertation consists of six experiments that employed affirmative and negative sentences embedded in discourse contexts. These contexts were designed to make the plausibility of a word within a target sentence contingent upon the presence or absence of negation. The main question was whether the negation-induced change in fit between target word and sentence context was detected immediately or nearly immediately upon its presentation (i.e. within the sentence/embedded proposition) or only after a significant delay. Additionally, the use of different discourse contexts and experimental paradigms allowed us to assess the impact of variations in task demands and the activation of different concepts on people's ability to update their expectations about upcoming information as a function of negation.

The remainder of Chapter 1 presents a selective overview of linguistic approaches to negation. First, we will introduce different criteria for identifying negative sentences and several ways of defining sentential negation, including alternatives to the view of negation as an operator acting on entire propositions. Then, the function and usage of negation will be discussed: The denial of an assumption derived from context or world knowledge is assumed to be the primary function of negation and the main reason for using negation even though it is an indirect form of communication.

Chapter 2 reviews the psycholinguistic literature on negation processing. The most basic finding is that negative sentences are harder to process than affirmative ones, and a number of different explanations have been offered for this. Negation can also lead to a reduction in the activation of concepts to which it applies, but this effect appears not to be obligatory, but rather to depend on contextual factors. Most studies have assessed the effects of negation only after the end of the sentence, and have found that the likelihood of observing effects increased with the delay from the negation. The one study that tested intra-sentential negation effects failed to find them (Fischler et al., 1983), which we suggest may have been due to the use of isolated sentences as stimuli. We propose that negation effects can be observed earlier within not just after the sentence with a negated concept as long as the sentences are embedded in an appropriate context.

The first set of experiments designed to test this hypothesis is presented in Chapter 3. The set consists of one ERP study and two timed verification experiments that use affirmative and negative sentences in contexts that describe a choice between two options. These contexts give participants sufficient information to anticipate the correct ending of the target sentence, whether it is affirmative or negative. The results of the ERP study suggest that participants could indeed use negation as a cue to adjust their expectations. However, their ability to predict the correct negative ending appears to depend on the inferences they draw from the preceding discourse: Which ending is the appropriate one for the negative sentence was not mentioned directly, but had to be inferred, and encoding this inference seemed to be critical for the ability to predict the correct negative ending later on. Task-related differences in verification times imply that the availability of processing resources also plays an important role in the timing of negation effects, as early negation effects could only be detected when participants had sufficient time and were not distracted by additional tasks. Since the electrophysiological and response time (RT) data show similar result patterns, we propose a common account for both in terms of the match between expectations and the actual stimuli being processed.

Chapter 4 discusses the second series of experiments, which employed the same paradigms as the first one. The contexts, however, were somewhat different, as the crucial information that allowed anticipation of the target sentence endings was presented in negative, rather than affirmative, form. This increased the relative predictability of endings of negative target sentences and led to stronger effects of negation. The results are consistent with the account developed in Chapter 3. They also provide support for the claim that negation reduces the activation of elements to which it applies by directing attention to a non-negated alternative.

Chapter 5 provides an overview of the specific aims and hypotheses of this dissertation and evaluates them in light of the outcomes of the six experiments. It discusses the implications of our findings for the timing of negation processing, the relationship between logical and natural language negation, negation effects on concept activation, and the importance of context in language processing. Finally, we propose additional experiments to test the validity of the account of negation processing that we proposed on the basis of the result of the research presented in this dissertation.

1.2 Definitions of Sentential Negation

Negation can have scope over linguistic units of different size. It can apply to sentence constituents like words (e.g., She is un*happy*) or phrases (e.g., They arrived not *long ago*) or to entire sentences (e.g., *I could* not *help him with his homework*). Psycholinguistic studies of negation have primarily dealt with negative sentences, which result from the wide-scoped sentence or predicate negation. Sentence negation has been defined in syntactic, semantic, and pragmatic terms, and different critieria have been proposed to identify negative sentences.

The standard analysis of negation in English was developed by Klima (1964), who followed a strictly syntactic approach. He described negation as a grammatical phenomenon, proposing distributional criteria to distinguish negative sentences from affirmative ones, even if they included negated constituents. According to these widely-used criteria, only negative sentences permit the occurrence of an *either*-clause (5), the *not-even* tag (6), affirmative tag questions (7), and a *neither*-clause (8).

(5) a. John is quite sad, and Mary isn't happy, either/*too.
b. John is quite sad, and Mary is unhappy, *either/too.

(6) a. Writers don't accept suggestions, not even reasonable ones.
b. Writers disregard suggestions, *not even reasonable ones.

(7) a. The Millers don't live far from here, do they/*don't they?
b. The Millers live not far from here, *do they/don't they?

(8) a. Stephanie doesn't like cilantro, and [neither/*so] does Sam.
b. Stephanie dislikes cilantro, and [*neither/so] does Sam.

Working within a generative grammar framework (Chomsky, 1957), Klima proposed that in the underlying structure, negation is generated in the leftmost position of the sentence and moves to its (usually sentence-medial) surface position through a sequence of syntactic transformations. Negation is thought to have scope over all sentence constituents to its right. At the level of deep structure, this includes all sentence elements. So negation has scope over the entire sentence.

Generative grammars require syntactic transformations to preserve meaning despite changes in word order (Katz & Postal, 1964). Jackendoff (1972), however, pointed out that the transformations proposed by Klima would involve changes in meaning when the negative sentence includes a quantified noun phrase (NP). Both sentences (9) and (10), for instance, can be derived from the same deep structure (11) following Klima's transformation rules. (10) additionally underwent the passive transformation (12) before the *neg*-particle was moved from the front of the sentence to its final position adjacent to the auxiliary, but this should not affect sentence meaning. The two sentences do differ in meaning and truth conditions, however: The truth of the corresponding affirmative, in its active (13) or passive (14) form, implies the falsity of (9), but it is compatible with the truth of (10).

(9) The book didn't impress many readers.

(10) Many readers weren't impressed by the book.

(11) Deep structure: *neg* (the book impressed many readers)

(12) Optional passivization: *neg* (many readers were impressed by the book)

(13) The book impressed many readers.

(14) Many readers were impressed by the book.

Jackendoff therefore suggested that negation is interpreted at the surface structure, rejecting the idea that all semantics must be captured at deep structure. He proposed a semantic definition of sentence negation that is based on a paraphrase of its surface structure:

(15) A sentence [X – neg – Y] is an instance of sentence negation if it can be rewritten as: It is not so that [X – Y].[1]

Keeping with the idea that negation is read at surface structure, Jackendoff placed only elements to the right of the negation marker at that level in the syntactic scope of negation as defined by Klima. Jackendoff's semantic definition of sentential negation, however, likens his view to the analysis of negation in propositional logic, where negation applies to an entire proposition or sentence (Frege, 1884, 1919).

Horn (1989) suggested an analysis founded in a different logical-philosophical tradition. Following Aristotle (Aristotle, 1961-1966; Engelbretsen, 1981a, b), he did not consider negation to be an operator, but a mode of predication, i.e. a way of connecting a subject and a predicate: Negation denies that the predicate applies to the subject, like affirmation asserts that the predicate is true for the subject. So (16) denies that predicate *being shy* applies to the subject *Doris*.

(16) Doris isn't shy.

(17) Pete does not agree with Matt.

Horn therefore used the term 'predicate denial' instead of 'sentence negation'. Predicate denials are associated with particular syntactic structures. In English, these structures involve the inflectional suffix *-n't* (16) or the particle *not* (17) associated with an auxiliary. This

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[1] According to this definition, (9) is an instance of sentence negation. (10), however, is not. Jackendoff suggests that it is an example of VP-negation. The verb phrase (*weren't impressed by the book*) is denied, but the quantification of the subject NP remains valid. A correct paraphrase would therefore be: For many readers it is not so that they were impressed by the book.

sentence-medial placement of the negation marker is not unique to English, however. A survey of 240 languages by Dahl (1979) revealed that negation is most frequently located in the proximity of the finite verb. By contrast, negation has not been found in a peripheral position at the very beginning or end of the sentence. Yet, this placement would be predicted from the propositional logic view of negation as an external operator or from Klima's (1964) proposal that negation is base-generated in sentence initial position. Horn pointed out that there would be no explanation for the consistent absence of this peripheral position if it was indeed the origin of negation at an underlying level of representation. He therefore took these cross-linguistic data as evidence against the view of negation as an external operator.

At a semantic level, Horn considered negation to have scope over the entire subject-predicate connection, i.e., the entire sentence. As in propositional logic, negation reverses the truth-value of the entire sentence. The predication may be denied because the subject actually does not exist or, more frequently, because the predicate describes a property that the subject does not possess. The truth of (18) may be due either to the fact that I do not own a dog or, more likely, that my dog is not one that bites.

(18) My dog doesn't bite.

Horn considered the part of the sentence that is responsible for the negation (or the failure of the subject-predicate connection) to be in the *pragmatic* scope of negation. The pragmatic scope comprises the elements whose role in the sentence is being denied; these elements constitute the information focus[2] of the statement. Prototypically, the subject of a sentence is considered given information (the topic) and therefore unlikely to be denied; the

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[2] A sentence is thought to be structured into *topic* and *focus*. The topic consists of the background or given information. The focus comprises the new information or the main point of the utterance.

pragmatic scope therefore comprises the predicate, the usual source of new information. So the pragmatic scope of (19) is the VP *didn't give the book to Sue*.

(19) Tom didn't give a book to Sue.

This assignment of topic and focus (and consequently pragmatic scope) is not obligatory, however. Stress, for example, can assign focus to different sentence constituents. In (20), stress assigns focus to the subject; so the sentence denies Tom's role as the person giving the book to Sue.

(20) Tom didn't give a book to Sue.[3]

Stress-focus can also be assigned to only parts of the predicate. In (21) and (22), for instance, different VP constituents are stressed; so they have different pragmatic scopes and interpretations. (21) denies that Sue is the person to whom Tom gave a book, while (22) denies that it was a book that Tom gave to Sue.

(21) Tom didn't give a book to Sue.

(22) Tom didn't give a book to Sue.

All four statements (19)-(22) have the same truth conditions, yet they differ in exactly to what negation applies. Importantly, it is always a connection between two elements, typically subject and predicate, that is being denied and not merely the truth of an entire proposition. Along the same lines, Moser (1992) defined negation as a relation of non-elementhood between a partner (the pragmatic scope) and a set specified by the frame (the remainder of the proposition). So (21) expresses that Sue is not an element of the set of entities to whom Tom gave a book. This analysis is very similar to Horn's, but it considers the distinction between partner and frame a logical-semantic one, while Horn merely conceived of it as a pragmatic fact.

[3] The underlined constituent is stressed.

In sum, there are different criteria for identifying a negative sentence, different definitions of what negation is, and different conceptions of what constitutes the scope of negation. The negative sentences that were used in the research presented in this dissertation are statements like (23) or (24). They meet all the criteria for sentential negation of each of the different approaches described herein, and the sentence-final target words (theatre, museum) are part of the scope of negation on all these analyses.

(23) So they didn't go to the theatre.

(24) Therefore FEMA didn't evacuate the museum.

In terms of processing, Horn's (1990) and Moser's (1992) as well as possibly Jackendoff's (1972) proposals should at least in principle allow negation to affect the target word. These analyses suggest that the negation marker precedes the structure(s) to which negation applies, i.e. the sentence predicate, the partner, or the scope of negation. The similarity between Klima's (1964) transformational approach and the propositional logic view, however, suggests that this analysis should be most compatible with the view that negation is processed (or begins to be processed) after the processing of the embedded proposition including the target word is completed.

1.3 Uses of Negation

1.3.1 Denial as the Primary Discourse Function of Negation

Negation is generally thought to serve at least two discourse functions: rejection and denial (Tottie, 1982). While rejection has an emotional component and is interpersonal in nature, denial pertains to the truth of propositions (Hidalgo Downing, 2000). Child language researchers have suggested that the denial category could be further subdivided into expressions of non-existence (e.g., *No cookie*.) and true denial (e.g., *It not all wet*.), where the former applies only to objects or persons, while the latter concerns entire propositions (Bloom, 1970; Brown, 1973; Pea, 1980b). It can be argued, however, that in both cases an entire proposition is denied. In the case of non-existence, this would be the proposition that a particular entity (such as a cookie) is present or exists. Thus, non-existence can be subsumed under the denial category.

In addition to denial and rejection, negation is also used as a toning-down or mitigating device (Giora, Balaban, Fein, & Alkabets, 2004; Giora, Fein, Ganzi, Levi, & Sabah, 2005; Givón, 1993; Leech, 1983). A negative sentence can introduce an idea or concept and hedge it at the same time, thereby reducing the force of the proposition (Giora et al., 2004). Thus, negation can be used to soften potentially critical or hurtful remarks in order to follow norms of verbal politeness or to manage social relationships (Colston, 1999; Givón, 1993):

(25) The food wasn't bad.

(26) I don't completely agree with you.

The general consensus, however, is that the predominant function of negation remains the denial of the corresponding affirmative proposition. Negation is typically used to contradict, to correct a wrong impression or belief, to point to a contrast between reality and a background assumption (Givón, 1979, 1984, 1989, 1993; Horn, 1989; Jespersen, 1917; Strawson, 1952; Wason, 1965). Although denial is not the only use of negation, and not every denial is expressed via negation, the prototypical and primary use of negation is considered to be the denial of a proposition (Horn, 1989), variably called presupposition (Givón, 1978, 1979), supposition (Clark, 1976), or background assumption (Givón, 1989).

The affirmative proposition that is denied may have been explicitly mentioned beforehand, may be implied in the prior discourse, or may be a stereotypical assumption, part of general cultural knowledge (e.g., Givón, 1989; Horn, 1989; Tottie, 1982). Fillmore (1985) distinguished two types of negation: context-free and context-sensitive. Context-dependent negation requires that the denied supposition be mentioned or implied in the preceding discourse or non-verbal context. Context-free negation, by contrast, is acceptable outside of such a discourse context, because the denial refers to some generally accepted knowledge. More specifically, context-free negation is thought to point out a deviation from a cognitive frame, script, or schema, which specifies the usual parts of an object, event, or situation (cf. Minsky, 1975; Rumelhart, 1980; Schank & Abelson, 1977). Such schemas act as expectations, and a negative sentence points to the defeat of an expectation. Pragmatically felicitous denial must either apply to an assumption that is mentioned in the discourse, or it must refer to a part of an invoked schema (Fillmore, 1985; Pagano, 1994; Shannon, 1981).

1.3.2 Using Negation Despite Its Markedness

Givón's Theory of Negation

According to Givón (1978, 1979, 1984, 1989, 1993), negative and affirmative sentences not only differ in their truth-value but also in their discourse presuppositions. These presuppositions do not conform to the traditional, logically-defined presuppositions, which require knowledge of the truth of a proposition. Rather, they correspond to what a speaker assumes that the hearer tends to believe. While affirmative sentences are used to inform a hearer about something that the hearer probably ignored, negative statements deny something the hearer was likely to believe (Givón, 1984). Given that the number of facts any given person knows or believes is infinitely smaller than the number of facts the person does not know about, the use of negation requires stronger assumptions about the knowledge or beliefs of the hearer: negation is presuppositionally marked[4].

Givón (1978, 1979, 1984, 1989, 1993) has also discussed the pragmatic markedness of negation in terms of perceptual saliency and the figure-ground distinction. Generally, changes or events are perceived against a background of stasis, inertia or non-events. If language is to be informative, it should follow this principle, and mainly provide new information about changes or events. As affirmative sentences describe events, they predominate. A negative sentence, by contrast, describes a non-event, and therefore requires a reversal of the figure-ground relation: the negative statement is uttered against a different kind of background, consisting of the corresponding affirmative (or discourse supposition).

Gricean Approaches

Grice (1975) introduced four conversational maxims thought to govern linguistic behavior in conversations: The maxim of Quality requires a contribution to be true. According to the maxim of Quantity, a contribution should be as informative as required. The maxim of Relation demands that a contribution be relevant to the conversation. Finally, the maxim of Manner states that a contribution should be perspicuous: clear, unambiguous, concise, and orderly. Listeners expect utterances to follow these maxims. The utterance "George has five children", for instance, implies that George has exactly five children (and not more than five), as

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[4] Markedness refers to a general organizing principle for linguistic categories. It was initially introduced to account for the contrast between the members of a sound pair differing in only one feature (Trubetzkoy, 1931, 1939), but Jakobson (1932, 1939) proposed extending the concept of markedness to grammar and the lexicon. Subsequently, a variety of linguistic oppositions have been analyzed in terms of markedness, including the contrast between affirmative and negative sentences, positive and negative adjectives, such as strong and weak, and singular versus plural nouns (Greenberg, 1966). The unmarked member is considered the default value from which the marked form (such as negation) is derived. The marked form is less frequent, occurs in a more restricted variety of contexts, and is phonologically or morphologically more complex.

otherwise the speaker would have said so. That is, the speaker is assumed to follow the Quantity maxim and be as informative as required. When, by contrast, a maxim is overtly violated, listeners take this as a cue to derive a non-standard implicature or inference from the utterance. Grice (1975) illustrated this with the example of a philosophy professor serving as a job reference for one of his students. The professor writes only that the student speaks excellent English and has attended tutorials regularly. Clearly, his answer is not as informative as it should be. Assuming that the professor is not completely uncooperative, he must have flouted the maxim of Quantity for a reason: he cannot provide more positive information about his student without violating the maxim of Quality.

Three Gricean maxims have been invoked to account for the use of negation and its relationship to a corresponding supposition: Quantity, Relation, and Manner. Horn (1978) suggested that the necessity of a supposition is implied by the maxim of Relation (Be relevant). The reason for the relevance of a negative sentence should be the ‘consideration of its affirmative counterpart’. Thus, the reply “My wife’s not pregnant” to the question “How’s it going?” (cf. Givón, 1978) could be seen to violate the Relation maxim. Alternatively, and more likely, the negative statement could exploit the maxim and implicate that the speaker’s wife might be pregnant (e.g., has been trying). Later however, Horn (1989) noted that his account failed to explain why the ‘consideration of its affirmative counterpart’ *must* be the justification for uttering the negative sentence.

Leech (1981, 1983) based his initial analysis of negation on the maxim of Quantity combined with what he called the sub-maxim of negative uninformativeness. Given that the number of negative facts about the world is infinitely larger than the number of positive facts (e.g., There is only one capital of Germany, while there are by far more cities in the world that are not Germany's capital.), negative sentences will generally be less informative than affirmative ones. Consequently, negative sentences should usually be avoided, and they should be used only when they are not less informative for a given purpose than an appropriate affirmative statement. This will be the case, for example, when the negative sentence is used to deny some proposition that is present in the context.

An argument based on negative uninformativeness does not hold in binary situations, however: Saying that someone's cat is not male is equivalent to saying that it is female; the same information is contained in both statements. Therefore, Leech (1983) proposed another account of negation with reference to the maxim of Manner, which requires utterances to be clear, brief, and direct. Negative sentences are longer, more complex, and less direct than affirmative sentences. Thus, they should be avoided even if they are informationally equivalent to an affirmative statement. The employment of negation must therefore be justified – by its usage for the denial of its affirmative counterpart.

Horn proposed a unifying account of negation within his neo-Gricean model of inference (Horn, 1984, 1989). The model maintains the maxim of Quality and reorganizes the remaining three maxims into two opposing, but interacting principles. The R-principle – based on the maxims of Relation, Quantity, and Manner – is oriented toward speaker economy. It requires an utterance to contain only what is necessary, i.e. no more than needed. The Q-principle – based on the maxims of Quantity and Manner – is motivated by hearer economy and requires utterances to be sufficient and as informative as possible. The two principles constrain the kind and amount of information contained in an utterance. Within this framework, a sentence is optimal when it provides just enough information for the purpose at hand, avoiding additional details. A negative sentence is therefore optimal when the speaker's intention is to correct a (presumed) misguided belief of the hearer: It is relevant to an explicit or implicit assumption and provides just enough information to correct the wrong assumption without providing any unnecessary detail.

Relevance Theory and Negation

Relevance Theory (Sperber & Wilson, 1986; Wilson & Sperber, 2004) posits that understanding an utterance is tantamount to deriving its contextual effects (CEs). A contextual effect is the result of the interaction between an input and one or more contextual assumptions (CAs). It can consist in a change of an existing CA's confidence rating, of the addition of new or the deletion of existing CAs. For an input to bring about a CE, that is to interact with the CAs, it must be relevant to these CAs. Only new information that is related to existing CAs can be relevant, i.e. bring about CEs. Unrelated new information would not be able to interact with CAs, and repeated old information would not lead to a change in the assumptions. The degree of relevance of an input is not only a function of its (potential) CE, however; it also depends on the effort involved in processing the input. Thus, of two utterances conveying essentially the same information, the one that is processed more easily will be preferred. Thus, Example (27) would be more relevant than (28) to someone interested in the dinner menu.

(27) We are serving chicken.

(28) Either we are serving chicken or (72 – 3) is 46.

Every act of communication is thought to occur under the presumption of optimal relevance, i.e. the presumption that the intended CE of an utterance is worth the speaker's effort as well as the presumption that the utterance is the most relevant one the speaker could have produced for the desired effect. Speakers are thus expected to produce optimally relevant utterances. As a consequence, direct communication should generally be preferred: If it can result in the same CE as an indirect utterance, it will be more relevant, as it is easier to process.

Negative statements can be considered an indirect form of communication (e.g., Colston, 1999), and should therefore be dispreferred. This only holds, however, if negation is used to communicate new information, to add a new CA or potentially strengthen a CA the hearer already holds. In this case, negative sentences should not be used because they are generally less informative, longer and harder to process. Negation, however, would be the means of choice if the speaker's goal is to eliminate or weaken an existing CA. It is thus the intention to deny a supposition that makes a negative statement relevant and felicitous.

1.3.3 Summary: Negation, Denial, and Supposition

The primary function of negation is the denial of a supposition. Negation is used to indicate that a (supposed) expectation was not met. This expectation or supposition is presumed to emerge from commonly shared knowledge or assumptions about the world, or it must have been mentioned or alluded to in the preceding discourse. In the absence of a context, only world knowledge (true or presumed) can be denied. Accordingly, isolated negative sentences would typically be used to deny something the listener holds to be true.

There are thus strong constraints on the use of negative statements, as they require the speaker to make significant assumptions about a listener's knowledge. Generally, negative sentences are therefore considered pragmatically marked. The denial function of negation, however, not only restricts its use, it also justifies it: A negative statement is more direct and informative than an affirmative statement to the extent that the speaker's goal is to change the listener's beliefs or assumptions.

CHAPTER 2

PROCESSING EFFECTS OF NEGATION

Negative sentence differ from their affirmative counterparts along many dimensions: They are marked by specific syntactic elements, have an often drastically different meaning, and serve particular discourse functions. The interaction of these syntactic, semantic, and pragmatic particularities gives rise to effects on how the sentence and the elements in the scope of negation are processed. At the most general level, it has been found that negative sentences are harder to process than affirmative ones, resulting in longer response times and higher error rates. In addition, negation often reduces the accessibility of concepts that it applies to, thereby changing sentence interpretation. Both types of effects can to a large extent be explained with reference to the representations involved in understanding negation, and both are strongly affected by the context in which negation is used.

2.1 Processing Difficulty

2.1.1 Evidence for Difficulty Increases Due to Negation

2.1.1.1 Sentence Comprehension and Completion

The first experiment explicitly aimed at comparing the difficulty of processing of positive and negative information employed a rather complicated sentence construction task (Wason, 1959). Subjects were given a sheet with a picture and an instruction to construct true or false conjunctive statements. The picture contained four numbered quadrants with a colored star in each. Below the display, the sentence that had to be completed was written either in an affirmative (1) or a negative (2) form:

(1) There is both Yellow / Green in 4 AND Red / Black in 3.

(2) There is NOT both Yellow / Green in 4 AND Red / Black in 3.

Subjects had to circle the two correct colors according to the instruction to make the statement true or false, presented on top of the picture. This task was very hard, and all response times were above six seconds, but the number of errors was low except for the false negative condition. Both the truth-value of the statement and its form (positive or negative) had significant effects on response times, with false statements taking longer to construct than true ones, and negative sentences leading to longer response times than positive ones.

Wason noted that in his initial experiment, not all conditions were equally specific. While the logically equivalent true affirmatives (TA) and false negatives (TN) had only one correct solution, there were several alternatives that would render false affirmatives (FA) or true negatives (TN). In his next study, which comprised a construction and a verification task, he used binary statements to make all sentences equally informative (Wason, 1961). There were four different sentence types that classified numbers as odd or even:

(3) …is an even number
(4) …is an not even number
(5) …is an odd number
(6) …is not an odd number

For the construction task, subjects had to provide numbers that would render the statements true or false according to a prior instruction. In the verification task, the statements were complete, such as (7) or (8), and subjects had to judge their truth. The reaction times in the construction task showed both a negation and a falsification effect, which was mirrored by the error data. Yet, only negation significantly increased response times in the verification task, while falsification had no such an effect. Furthermore, TN resulted in the most verification errors, even though FN were most difficult in construction.

(7) Four is not even.

(8) Five is not even.

Wason attributed this data pattern to the number of mental transformations from negative to positive that are involved in the two tasks for the different statement types. An example of such a transformation would be the recoding of *not even* into *odd*. For construction, both falseness and negation necessitate transformation of the statement, so that the appropriate response can be found: To complete a FN like "… is not an even number", a subject presumably would first transform *not even* into *odd*, but then reverse *odd* to *even* in order to find a number that makes the statement false. In verification, on the other hand, a FN is the simple denial of a truth (7), while a TN is the denial of a falsity (8), that is, a double negative. Wason's intuitive interpretation was largely in line with a number of formal models that were subsequently developed (e.g., Clark, 1976; Trabasso et al., 1971).

The notion that negation renders verification difficult did not remain unchallenged, however. Wales and Grieve (1969), for example, argued that such negation effects could be ascribed to 'confusability'. After informing subjects that three numbers had to add up to 15, the following type of statements were presented:

(9) Given x and y, the next number is z.

(10) Given x and y, the next number is not z.

Half of the statements were true, the other half false. For one group of subjects, the numbers added to 15 for TA and FN, and to 14 and 16 for FA and TN. For another group however, FA and TN were changed to be less confusable: they added up to sums further away from 15 (closer to 6 or 24). The two groups did not differ in their response times to TA and FN, which had been the same for both. Response times to FA and TN were significantly faster in the less confusable condition. Wales and Grieve took this as evidence that the negation effect was due to confusability, and not an inherent difficulty of negative statements.

Yet, as pointed out by Greene and Wason (1970), there was a problem with the design and interpretation of this study. The statements that the first group had to evaluate were all equally confusable, since the TA and FN sums were adjacent to the non-target values 14 and 16, and the FA and TN sums were adjacent to the target value 15. For the second group, only FA and TN had been rendered less confusable by moving the sums away from the critical value of 15. Conversely, TA and FN were still as difficult and confusable since their sum of 15 was still adjacent to 14 and 16, which were values that would have resulted in a different judgment. The differential facilitation for FA and TN was therefore expected, but not as meaningful as Wales and Grieve maintained. In addition, the manipulation had not eliminated the basic negation effect, questioning Wales and Grieve's conclusion.

A neuroimaging study by Carpenter and colleagues (Carpenter, Just, Keller, Eddy, & Thulborn, 1999) lent further support to the claim that negative sentences are harder to process than affirmative ones. Here, the task consisted in comparing sentences of the form "It is (not) true that the star is above the plus" against pictures with a plus above or below a star. As in previous studies, subjects took longer to judge negative statements, but in addition they showed increased activation in temporal and parietal areas presumably subserving the linguistic and visuo-spatial analyses of the materials. This was taken to reflect the higher processing load associated with negation.

Increased processing difficulty was reported not only for sentences containing *not*, but also for sentences containing other kinds of negatives, such as negatively prefixed adjectives (e.g., *unhappy*) and negative quantifiers (e.g., *few*). Sherman (1976) had subjects judge the plausibility of sentences like (11) and (12), which contained up to four psycholinguistic negatives (including marked adjectives and verbs): *no one*, *not*, a prefixed adjective, *doubt*. Both response time and error rates correlated positively with the number of negatives (only one of which could have been *not*).

(11) Because he often worked for hours at a time, no one believed that he was not capable of sustained effort. (plausible)

(12) He liked to let others make decisions and thus everyone doubted that he would be unsuited for the director's job. (not plausible)

Glass, Holyoak, and O'Dell (1974) demonstrated that negative quantifiers made the completion of quantified statements more difficult. Twenty nouns were combined with one of five quantifiers – *all*, *many*, *some*, *few*, and *no* – and presented in incomplete sentences, such as "All professors are…". For each statement, subjects had 30 seconds to fill in as many adjectives and nouns as they could think of. The number of completions for negative quantifiers (*no* and especially *few*) was overall lower than for positive quantifiers. Glass and colleagues proposed that subjects could only generate positive attributes directly; in order to produce negative ones, they had to find contradictions to the positive attributes in a second step. This explanation was supported by the finding that the responses to negatively quantified statements were very often the opposites of those given to the equivalent positive sentences.

2.1.1.2 Reasoning

Before sentence verification and construction became of interest, Bruner, Goodnow, and Austin (1956) had observed that subjects appeared unwilling to use negative information to form concepts. Instead, they seemed to form hypotheses about the concepts and matched their predictions against positive instances. Negation effects have subsequently been reported in a number of other reasoning experiments. Evans (1972), for example, found that subjects made fewer correct inferences in a conditional reasoning paradigm when the antecedent of a conditional was negative. Given a rule of the form if *p then q* and asked what would follow given *not q*, 91% answered correctly *not p*. If the rule was *if not p then q*, however, only 38% of responses were correct. To explain this, Evans suggested that subjects had trouble denying a negative statement or recognizing that a double negative is equivalent to affirmation. One should note, however, that other accounts of negation effects in reasoning do not assume any difficulty associated with the use of explicit negation, but explain the data with reasoning biases (e.g., Evans, 1998) or the difficulty of constructing negatively defined sets (Oaksford, 2002).

Lea and Mulligan (2002) studied the impact of negation on deductive inferences in more natural text passages. They contrasted two kinds of inferences: *or*-elimination and *not-both* elimination. In *or*-elimination, the rule *a or b* is given, and upon learning that *not a*, *b* can be inferred. For *not-both* elimination, the rule is *not both a and b*, and the truth of *a* implies *not b*. The important difference between the two inference types is that not-both elimination requires inferring a negative, and Lea and Mulligan thus hypothesized that these inferences would be less readily made than the positive inferences following from the *or*-elimination. To test this hypothesis, Lea and Mulligan presented text passages involving one of the two types of inferences and recorded reading times for a target sentence, which was inconsistent with the inference. The increase in reading time due to this inconsistency (compared to a control condition) was similar for both inference types. Thus, no negation effect was found.

In a subsequent experiment, however, a difference between the two conditions could be detected. Following the presentation of passages that induced the inference of a concept or its negation, the concept appeared on the screen as a naming probe. Compared to a no-inference control condition, the concept was primed, and subjects named the probe faster in the *or*-elimination condition with the positive inference, but not in the *not-both* elimination condition where the inference had been negative. Lea concluded that negation did not affect the deductive reasoning processes per se, but did have an effect on the linguistic representations.

2.1.1.3 Memory

Memory also has been shown to be affected by negation contained in the material to be remembered as well as by negative instructions. Cornish and Wason (1970) employed an incidental learning task to reveal the effects of negation in the sentence material. Subjects first read affirmative and negative sentences as clues about an object they had to guess. In the subsequent, unannounced recall phase, they remembered the affirmative sentences significantly better than the negative ones. Most errors with negative sentences involved a change in syntax rather than semantics: negated adjectives were recalled as their opposites without the preceding *not*. In fewer cases, *not* was simply omitted.

Similar results were found in an explicit memory experiment conducted by Clark and Card (1969). It used negative and affirmative sentences with marked or unmarked adjectives that were comparative (e.g., *better than*) or equative (e.g., *as good as*). Subjects recalled more affirmative sentences, more sentences containing unmarked adjectives, and more sentences expressing "strictly more than" than those expressing "more than or as much as" (e.g., *not better than* or *as good as*). This was due to more verbatim recall for these preferred sentence types as well as more reconstructions of the preferred from the non-preferred sentence type than vice versa. Clark and Cark explained these transformations by the loss of a semantic feature from memory. According to this account, negatives would place higher demands on memory and therefore be more prone to error.

Not only storage, but also search processes in memory can be affected by negation. Howard (1975) demonstrated this in a memory-scanning task using the Sternberg paradigm (Sternberg, 1969). Subjects were asked to memorize sets of different numbers of letters and then to report whether probes were or were not part of the set. On *plus* trials they had to answer "yes" if the probe was in the set and "no" if not, but on *minus* trials the instruction was inversed, and subjects needed to respond with "no" to items from the set and "yes" to probes that were not part of the memory set. Response times were overall longer in the *minus* condition, which could be explained by response reversal: positive probes had to be rejected and negative ones confirmed. In addition, the effect of set size, an increase in response time with set size, was larger in the *minus* condition. Howard attributed this to the cost of storing the probes as negative information, which resulted in a general slowing of the scanning process. The response time increase was paralleled by an increase in error rates in the *minus* condition. Overall, the experiment demonstrated negation effects on the efficiency of memory processes, which reduced both precision and speed of task execution.

2.1.1.4 Acquisition

The first systematic study of the acquisition of negation was mainly concerned with the form of negation in early child language. Klima and Bellugi (1966) identified three phases in the development of negative sentence production, ranging from the placement of *no* or *not* at the beginning or the end of an utterance (e.g., “No the sun shining”) to the correct incorporation of an auxiliary and the negation marker within the sentence (e.g., “Paul didn’t laugh”).

The analysis of syntactic development was subsequently complemented by descriptions of the use of negation for different communicative functions. Bloom (1970) studied three children learning English, and proposed that negative sentences were initially used to signal nonexistence (“Cookie all gone.”), later to reject actions or objects (“No nite-nite.”), and finally also to deny statements (“It not all wet.”). She acknowledged, however, that “nonexistence first” might be an artifact resulting from the restriction to negative utterances with an overtly expressed referent (Bloom, 1970, 1991). This was indeed confirmed. Extending the analysis to one-word utterances and gestures like headshakes, Vaidyanathan (1991) and Pea (1980a) showed that rejection was developmentally prior to nonexistence. Pea proposed that rejection was followed by disappearance (Bloom’s nonexistence) and truth-functional negation (denial). While Tottie (1982) suggested that nonexistence and denial might be equivalent, both Bloom (1970) and Pea (1980a) argued that denial applies to a more abstract proposition and not simply to a perceivable external referent. This would explain its relatively late appearance in children’s productions (around 2 years).

A full understanding of truth-functional negation does not become available to children until after they produce denials. Pea (1980b) recorded 18 to 36 months old children’s spontaneous use of negation in responding to true and false affirmations and denials. The experimenter asked the child to give him a toy and then made a simple statement about the object, e.g., (13) through (16) referring to a ball.

(13) That is a ball. (TA)

(14) That is a car. (FA)

(15) That is not a car. (TN)

(16) That is not a ball. (FN)

Children usually responded to false statements by correcting the experimenter. All children over 30 months of age as well as the younger girls used “no” more often in their replies to FA than to TA. Also, children responded with the name of the referent more often to FN than TA to correct the experimenter’s denial of a truth; they used “bear” in their response to the experimenter’s claim “it is not the bear” while actually referring to a bear. TN, however, were problematic for many children. Although some children responded correctly (“yes, it’s not”), it was clear that they found these sentences very hard, with one child claiming that it was “a funny thing to say”. Since the study relied on spontaneous utterances, only differences between conditions could be observed, but absolute measurements of understanding were not possible.

A study with English- and Korean-speaking children between the ages of 3 and 5 years explicitly asked the children to judge statements, which allowed for the assessment of overall correctness for each condition (Kim, 1985). The children were shown a puppet that “was just learning to speak” and told that they had to teach the puppet by responding “right” or “wrong” to its statements. The puppet said simple sentences like “This is not an apple” while a picture of an object was shown. While the children almost uniformly responded correctly to affirmative sentences, the percentage of correct responses was lower for negative statements. TN were especially difficult. Three-year old English-speaking children answered “right” correctly only 33% of the time, but the percentage rose to 62% in 5-year olds. The proportions of correct answers to TN were even lower for the Korean-speaking children. FN were also harder than affirmatives, but English-speaking children still answered correctly 80 to 90% of the time, and Korean-speaking children 70 to 80%. Kim concluded that some understanding of the logic of negation must already be present in 3-year olds, since the majority of them responded correctly to FN. The high failure rate on TN should then be attributed to the fact that that these sentences are pragmatically anomalous and removed from the communicative context; thus, the children would have to rely strictly on logic, making more mistakes as a result.

The acquisition findings fit with the general picture of negation difficulty. Children acquire the different uses of negation gradually with truth-functional negation appearing last. Even after they use denial negations for the first time, children continue to have problems judging the truth of negatives, especially TN. The delayed acquisition of negation is mirrored by the processing difficulty associated with negative statements observed in adults. As we will see in the next chapter, both adults' and children's difficulty with negation can be alleviated by a communicative context that makes negation more plausible.

2.1.2 Explanations

The variety of tasks in which negation has been used is matched by the diversity of theories that have been proposed to account for the apparent difficulty of processing negative sentences. There have been three main approaches to explaining the difficulty with processing negation: syntactic, semantic, and pragmatic accounts. The syntactic and semantic models of the 1960s and 1970s treated negation as a grammatical transformation or an embedding proposition, respectively. According to both proposals, the difficulty in processing negative sentences results from the additional mental operations that are needed to process the negation. Pragmatic accounts, by contrast, have argued that negative statements are not particularly difficult in natural language use, but they do require a certain communicative context which renders them interpretable and plausible. Finally, it has recently been suggested that negation is implicitly encoded in a succession of two representations – that of the expected and that of the actual state of affairs – and that it is the necessity of constructing two representations (as opposed to one for affirmatives) that renders negative sentences more difficult if they are not used in used in pragmatically appropriate contexts.

2.1.2.1 Negation as a Grammatical Transformation

According to Chomsky's theory of transformational grammar, most sentences are derived from more basic ones by applying grammatical transformations. A negative sentence like (2), for example, would result form the application of the appropriate transformation to a basic kernel sentence, such as (17).

(17) The boy has kicked the ball.

(18) The boy hasn't kicked the ball.

Shortly after the publication of this proposal (Chomsky, 1957), George Miller and his students adopted the theory of transformational grammar as a psychological model of sentence processing (e.g., Mehler, 1963; Miller, 1962; Slobin, 1966). They devised several experiments aimed at demonstrating the psychological reality of grammatical transformation by revealing effects of transformational complexity on processing difficulty. Negation was not the main interest of this line of research, but like passivization, and interrogation, served as examples of such transformations.

Mehler (1963), for example, tested the effects of these transformations on sentence recall using active and passive, affirmative and negative, as well as declarative and interrogative sentences. The corresponding transformations were applied to eight kernel sentences, i.e., active, affirmative, declarative sentences. Subjects listened to the sentences five times, each time in a different order. After each presentation, they were asked to recall the sentences and write their answers in booklets that contained words from the sentences as prompts. As Mehler had predicted, subjects recalled kernel sentences better than sentences that had undergone transformations. Moreover, subjects tended to simplify the sentences: they omitted transformations, like passive voice or negation, more often than they added them. Mehler suggested that subjects encoded the sentences in the form of an underlying kernel (the semantic component) with syntactic tags denoting the specific transformations applied to the sentence. These tags could be lost, resulting in the observed simplifications.

In addition to claiming that grammatical transformations would make sentences harder to process, Miller (1962) proposed that transformations of different complexity would also take different amounts of time. More precisely, he suggested that the passive transformation was more complex than the negative transformation and would therefore taker longer. Furthermore, the time needed to carry out two transformations should be longer than that necessary for one transformation. Miller tested these hypotheses in a sentence matching experiment. He constructed sentence pairs that differed by one or two transformations, i.e. active, passive, or both. This resulted in six kinds of pairs: active affirmative vs. active negative and passive affirmative vs. passive negative (negative transformation); active affirmative vs. passive affirmative and active negative vs. passive negative (passive transformation); active affirmative vs. passive negative and active negative vs. passive affirmative (negative and passive transformation). For each trial, eighteen pairs of the same kind were distributed over two lists, and subjects were timed while they matched the sentences of the first list to their transformed counterparts in the second list. In a control condition, the sentences in the first and the second list were identical.

Miller subtracted the time that subjects took in the different transformation conditions from the time for the appropriate control conditions. This difference, called transformation time, was thought to represent the time it took to execute the transformations. In accordance with Miller's predictions, the transformation time for passivization was longer than that for negation. Moreover, subjects took longer to carry out two transformations than any single transformation. The double transformation time, was, in fact, quite close to the sum of passivization and negation time. Miller viewed this as support for the transformational theory of sentence processing.

Miller's and Mehler's experiments, however, did not really require comprehension of the sentences. In both studies, subjects could rely on a relatively superficial analysis that did not require an understanding of the meaning of the sentences. Subsequent experiments by others (e.g., Gough, 1965; Slobin, 1966) employed sentence verification paradigms, a crucial part of which is semantic analysis. These studies did not refute that transformations play a role in processing sentences, but they did demonstrate that syntactic operations alone cannot account for the difficulty of processing negation.

Gough (1965) had subjects verify the truth of sentences with respect to pictures. The sentences were affirmative or negative statements in active or passive voice, such as (19) or (20).

(19) The girl hit the boy.

(20) The girl wasn't kicked by the boy.

After auditory presentation of a sentence, subjects were shown a picture. Upon verification, the subject pressed one of the response buttons, labeled *true* and *false*. The response times showed the expected main effects of falsity, negation, and passive voice, all of which resulted in a slowing of response times. There was, however, also an interaction between truth-value and negation: while TA were verified faster than FA, this truth-value effect was not present for negatives.

Gough reasoned that negation must have a semantic component, since it interacted with the semantic truth-value factor. He also pointed out alternative interpretations for the overall higher response-times of negatives and passives: Negative and passive sentences are longer and less frequent than active affirmatives, and response times might correlate with both length and frequency.

A corpus analysis by Golman-Eisler and Cohen (1970) confirmed Gough's intuition about the frequency of passives and negatives. In seven samples of about 100 clauses each, between 80 and 90% of all sentences were active and affirmative. Negatives and passives constituted less then 11% of the total utterances across samples. Golman-Eisler and Cohen argued that in view of these data, the difficulty associated with passives and negatives could not be taken as evidence for transformational complexity.

A sentence-picture verification experiment conducted by Slobin (1966) likewise questioned the ability of syntactic theory to explain the difficulty of negation. Slobin compared the syntactic theory, which predicted that negatives should be evaluated faster than passives, with an alternative account, according to which the semantic difference between affirmation and negation should outweigh the effect of transformational complexity. The results confirmed the importance of the semantic variable: in adults as well as children, response times for negative sentences were longer than those for passives.

Slobin's data as well as similar results by McMahon (1963) convinced Miller (Miller & McKean, 1968) that semantic operations were more likely to account for the effects of negation on sentence processing. Neither Miller nor Slobin, however, offered an account of the nature of this semantic mechanism and of how it affected the processing of negative sentences. Gough (1965) proposed that initially, the kernel sentence would be compared with the picture. The derived truth value would then be flipped because of the presence of the negative tag. This explanation is quite similar to the semantic models of sentence and concept verification that were subsequently developed by Trabasso (Trabasso et al., 1971) and Clark (1976).

2.1.2.2 Semantic Models of Statement Verification

Sentence verification studies firmly established that negative sentences were harder to process than their affirmative counterparts. It also became clear that some semantic factor must be involved in the explanation of this phenomenon. There is, however, an additional pattern in the data for which an account is needed: a number of experiments showed that the effect of truth-value could vary between affirmative and negative statements. TA were consistently easier to verify than FA. TN, by contrast, were often found to be as difficult as FN (Gough, 1965) or even harder (response times in Wales & Grieve, 1969; errors in Wason, 1961). Yet, the opposite pattern, with TN being easier than FN, has also been reported (McMahon, 1963).

The observed interactions between truth-value and negativity were a major motivation for the development of semantic models of sentence verification. This interaction showed that negation did not simply add a certain processing cost to a sentence. Rather, negation seemed to interact with the semantic aspects of a statement in a principled manner. In their search for an explanation of the data patterns, Trabasso (Trabasso et al., 1971) and Clark (1976; Clark & Chase, 1972) independently developed highly similar accounts of the verification process. Subsequently, Carpenter and Just (1975) proposed a model of sentence comprehension that shared many features with these prior accounts, but attempted to explain a wider variety of phenomena with fewer parameters.

Trabasso's Coding-Matching Model

Trabasso developed the coding-matching model to account for a series of verification experiments in which subjects compared verbally presented binary attributes of color or shape (*orange* vs. *green* and *large* vs. *small*) with the properties of a visually displayed geometric figure (Trabasso et al., 1971). The attributes were expressed as an affirmation (e.g, *green*) or as a negation (e.g., *not small*). They were presented either before or after the pictures. When the descriptions were shown first, statement form and truth-value had additive effects: subjects responded faster when the statements were affirmative rather than negative, and when the statements were true rather than false. When the pictures preceded the descriptions, however, an interaction between truth-value and negativity appeared: TA were verified faster than FA, but response times for TN were longer than those for FN.

Trabasso used the coding-matching model to explain how order of presentation, the only factor that varied between these experiments, could lead to the difference in verification time patterns. According to the model, a subject starts by coding the first input. At this stage, a negative statement is transformed into affirmative form if possible, i.e., if the attribute is binary. Otherwise it has to be coded as a feature with a negative tag. Then the second input is coded, so that the features of the two representations can be matched. If a mismatch occurs, the response index will be changed from *true* to *false*. An additional response change is necessary if exactly one of the two representations has a negative tag; if neither or both are tagged, no response change occurs. Each mismatch and flip of the response index translates into an increase in response time.

The model's predictions matched the data patterns of the two experiments described above. In the case where the picture preceded the statement, the features of the object (e.g., *green* and *small*) were encoded first. Then, the sentence was encoded without transformations, whether it was negative or affirmative. A TA (e.g., *small*) did not result in any mismatches or response changes. FA (e.g., *large*), by contrast, triggered a feature mismatch, setting the response index to *false*. Consequently, FA took longer to verify than TA. The picture was reversed for negative descriptions. For FN (e.g., *not small*) the features of both inputs matched, but the presence of a negative tag in the statement representation caused a response change to *false*. TN (e.g., *not large*) had the longest verification times because they produced two response changes, one due to a feature mismatch and one due to the negative tag.

The experiment in which descriptions were presented first produced a different pattern of verification times, because it allowed for the transformation of negative statements (e.g., *not orange*) into affirmative ones (*green*). Note that this was possible because two conditions were fulfilled: the attributes were binary, and the statements were presented and coded first. This transformation added a constant amount of time to the response times for both kinds of negative statements. After the transformation, however, the representations of the negative descriptions were equal to those of the affirmative ones. As a result, false statements took longer to verify than true ones (because of a feature mismatch), whether the description had been affirmative or negative.

Additional evidence for the transformation of negative statements into affirmative representations came from an experiment in which the storage time of the statements was recorded. In this paradigm, subjects saw the description and pressed a button when they were ready to view the object. Then they pressed the *true* or *false* button according to whether the statement corresponded to the picture or not. The storage stage was longer for negative than for affirmative descriptions, a difference that Trabasso attributed to the time it took to transform the statements. In the beginning of the experiment, negative descriptions still took longer to verify than affirmatives, but after several blocks, both statement types were verified equally fast. This was predicted by the model, since all coded representations should be affirmative, once the subjects had learned to apply the transformation consistently.

Trabasso also used the model to explain the results of previous verification studies such as Slobin (1966), which had showed an interesting difference between adults and children. While truth-value and negativity interacted in the children's data, no such effect was found in the adults' verification times. Slobin had presented the sentences first, which allowed the adult subjects to transform negative sentences before comparing them with the depicted situations. True sentences, therefore, were verified faster for both affirmative and negative statements. Trabasso suggested that the children might not have used the transformation strategy. Consequently, the negative sentences were encoded with a negation tag, which resulted in FN being faster than TN to verify. The coding-matching model proved useful in explaining a variety of experimental results. Its credibility was further increased by a similar account of sentence verification offered by Clark (1976; Clark & Chase, 1972).

Clark's 'True' and 'Conversion' Models of Negation

Clark's general model of sentence-picture comparison can be explained best with reference to the particular verification task used by Clark, Young, and Chase (Clark & Chase, 1972; Young & Chase, 1971). In this task, subjects were shown one of two pictures of a star and a plus ($\stackrel{*}{+}$ or $\stackrel{+}{*}$) along with a sentence describing a particular spatial configuration of the two objects. The sentence could be phrased affirmatively or negatively, and the spatial relationship was expressed using either *above* or *below*. This resulted in eight different sentences, such as

(21) and (22). Subjects were asked to compare the sentence and the picture and to decide if they matched.

(21) The plus is above the star.

(22) The star isn’t below the plus.

Like Trabasso’s coding-matching model (Trabasso et al., 1971), Clark’s general account offers two alternatives for the encoding of negative sentences (Clark, 1976; Clark & Chase, 1972): the ‘true’ and the ‘conversion’ method. According to the ‘true’ model, the negative statement (22) is represented as *(false (star below plus))*, consisting of a positive inner proposition *(star below plus)* embedded in a negative outer proposition *(false ())*. If the ‘conversion’ method is applied, however, the negative statement is converted into a positive proposition. Thus, (22) could be represented as *(star above plus)* by omitting the negation index and converting the preposition. Clark (1976) noted that the ‘true’ method would work under all circumstances, while the ‘conversion’ method could be applied only in binary situations (such as the task he used). For both methods, encoding a negative statement takes longer than coding an affirmative sentence, albeit for different reasons: the ‘true’ method requires the representation of an outer proposition, and the ‘conversion’ method involves a mental transformation of the negation into an affirmation.

During the comparison stage that follows the encoding of both inputs, the representations are compared, starting with the innermost proposition. If they do not match, the response index (initialized to *true*) is flipped. Then the embedding propositions are compared, and a mismatch likewise results in a truth index change. Each mismatch and the ensuing change of the response index adds a constant amount to the verification time.

Clark and Chase (1972) used the ‘true’ model to explain the response time pattern in their first experiment, in which subjects were instructed to attend to the sentences first.

Verification times in this experiment showed an interaction between truth and negativity, with an ordering of response times as follows: TA < FA < FN < TN.

According to the 'true' model, subjects encoded the sentences first, as instructed. Negative statements were represented as a positive proposition embedded in a negative one, which added a constant amount to the time necessary to verify them. Then the pictures were encoded, and following Clark's principle of congruency (Clark, 1976), their representations matched the form of the inner proposition of the sentence representations (experiment 3 in Clark & Chase, 1972 provided evidence for this assumption). That is, if the sentence representations contained *below*, so did the picture representations, and vice versa. For example, after reading (22), corresponding to *(false (star below plus))*, the picture [] would be represented as *(plus below star)*.

To illustrate the processes of the comparison stage, let us look at sentences (23) through (26), all using the preposition *above*, and the picture []. In this case, the picture was represented as *(star above plus)*, which could also be written as *(true (star above plus))*.

(23) The star is above the plus. (TA)
(star above plus)

(24) The plus is above the star. (FA)
(plus above star)

(25) The star isn't above the plus. (FN)
(false (star above plus))

(26) The plus isn't above the star. (TN)
(false (plus above star))

The representation of the TA (23) was identical to that of the picture; the response index did not have to be changed, and the verification time did not increase. For the FA (24), the comparison with the picture resulted in a mismatch of the inner propositions. The response index was therefore flipped to *false*, causing longer verification times than for TA. The FN (25) produced even longer response latencies. Its inner proposition *(star above plus)* matched that of the picture, but its outer proposition *(false ())* did not. The time needed to flip the response index to *false* was added to the extra time due to encoding the negative proposition, resulting in the observed increase in verification time. For the TN (26), both the inner and the outer propositions conflicted with those of the picture. Consequently, the response index first changed to *false* and then back to *true*. Together with the additional encoding time for the negation, this produced the longest response times.

Clark and Chase (1972) built a quantitative model to account for the verification latencies. It contained free parameters for negation (consisting of negation encoding and the mismatch of the embedding propositions), the mismatch of the inner propositions, and the encoding of *below* (as compared to *above*). The latter parameter is justified by the markedness of *below*, and, in this experiment, adds only a constant to sentences containing *below*. Clark and Chase estimated the parameters from the response time data, and the parameterized model accounted for 99.8% of the variance in the data, providing strong support for the 'true' model.

While subjects did not seem to convert negative statements into positive ones spontaneously, they could be instructed to do so. Young and Chase (1971) used the same materials as Clark and Chase (1972), but asked their subjects to transform the negative sentences by omitting the negation and exchanging *above* and *below*. This conversion added a constant to the verification times for negative sentences. After encoding, however, the representations for affirmative and negative statements differed only by the preposition. Since the pictures were subsequently encoded in the same form as the sentences, this had no effect on response time. False statements produced a mismatch of propositions, true ones didn't.

Therefore true statements were uniformly verified faster than false ones, producing the following order of response times: TA < FA < TN < FN. The quantitative model with parameters for conversion time, mismatch time, and *below* time explained over 95% of the variance in these data.

Clark (1976) noted that while subjects did not apply conversion obligatorily (cf. experiment 1 by Clark & Chase, 1972), they could use it spontaneously under certain circumstances. Sometimes, subjects would vary in their use of strategies although they were performing the same task. This could, for example, explain the outcome of Wason's (1961) study on the verification of odd and even numbers. The results of Wason's experiment did not conform to the predictions of either the 'true' or the 'conversion' model. TA were verified significantly faster than FA (as both models predicted), but TN and FN were evaluated about equally fast. This pattern would be expected, however, if some subjects employed the 'true' and others the 'conversion' method. Indeed, Wason had asked his subjects to explain how they carried out the task, and about half of them said they converted *not odd* to *even* and vice versa, while the other subjects reported using the equivalent of the 'true' method. The results of several other verification studies (e.g., Eifermann, 1961; Gough, 1965; Slobin, 1966; Wason & Jones, 1963), too, could be explained by the differential application of the 'true' and 'conversion' methods (Clark, 1976).

Within the framework of his sentence-picture comparison model, Clark (1976) also argued that the pragmatic notion of supposition could help explain the way a picture was encoded when it was to be compared to a negative sentence. Since negative statements are usually used to deny an affirmative statement, it would make sense to compare the sentence against a representation that is coded in terms of its supposition. To illustrate this point, Clark reinterpreted a study by Just and Carpenter (1971) that aimed at comparing the effects of three different kinds of negation on picture encoding. Subjects in this experiment verified affirmative and negative statements about the color of (a subset of) dots with respect to a display of 16 colored dots. There were syntactic negatives with a negative particle (*not*, *none*, *no*), syntactic negatives without the negative marker (*few*, *scarcely any*, *hardly any*), and what Just and Carpenter called semantic negatives (*a minority*, *2 of the 16*, *a small proportion*), expressions denoting small quantities but lacking the syntactic properties of negatives as defined by Klima (1964). Syntactic negatives and their affirmative counterparts were verified against pictures of dots that were all black or all red. In the other two conditions, the display contained two dots of one color and 14 of the other color.

The results for both syntactic negation conditions conformed to the predictions of the 'true' model, while the verification times for the 'semantic negatives'[5] resembled the prediction of the 'conversion' model in that there was no interaction between truth and 'negativity'. Clark (1976) recast Just and Carpenter's explanation for these findings in terms of supposition. For the two syntactic negations, subjects had encoded the pictures according to the principle of congruency, which was necessary for the 'true' model to apply. Expressed in terms of supposition, subjects had encoded the part of the pictures that corresponded to the supposition, i.e. the majority that was denied by the negation. In the case of the negatives containing *no* or *not* (27), this was not surprising, since the display was uniform and the subjects had to encode all the dots. For the negative quantifiers (28), however, they could have chosen to focus on the minority or the majority of the dots. The conformity to the 'true' model suggested that they had encoded the sentences as a denial of the supposition that the majority

[5] Single quotes are used for negative terms when they refer to the 'semantic negation' condition in order to distinguish it from true negation according to Klima's (1964) tests.

of the dots were of a certain color and represented the pictures in terms of this supposition, i.e., the majority (e.g., *(most dots are black)*).

(27) There are no red dots.
(false (there are red dots))

(28) Few of the dots are red.
(false (most dots are red))

The situation was different for the 'semantic negation' condition. Here, only the affirmatives (*majority*, *14 of 16*, *large proportion*) and the corresponding pictures were encoded with respect to the majority of dots, while the minority was represented for 'negatives' and the accompanying pictures. This could be explained by the fact that 'negatives' like *a small proportion* simply make a positive statement about the minority. In fact, they could be said to affirm a supposition about the minority. There were no embedding *(false ())* propositions for positive or 'negative' statements, and the inner propositions were congruent with those of the pictures. For a situation like this, no truth-by-'negativity' interaction is predicted. According to the general model, the falsification process should be the same for FA and 'FN', and the data confirmed this prediction. Clark's sentence-picture comparison model could thus not only account for a variety of sentence verification data, it also proved useful in establishing a psychological distinction between true linguistic negatives and other expressions that might refer to equally small quantities, but do not pass linguistic negativity tests.

Carpenter and Just's Model of Sentence Comprehension

Carpenter and Just (1975) developed a verification theory that bears an overall resemblance to both Clark's and Trabasso's accounts (Clark, 1976; Trabasso et al., 1971), but they postulated only one mental operation to explain the data, while attempting to account for wider variety of phenomena. Their proposal was motivated by the observation that there were systematic relationships among the response times found in previous studies. According to their analysis of the literature, negation time (the difference between FN and TA) was roughly a multiple of falsification time (the difference between FA and TA). This, Carpenter and Just concluded, was an indication that all differences in verification time could be explained by a single mental operation and the number of times it was executed. In addition, negation time was always either twice or four times as long as falsification time. Carpenter and Just attributed this to the difference in scope of negation. Clark (1976) had already observed that negation with a wider scope had a greater effect on response times, but he had not provided a mechanistic account. Carpenter and Just offered an account from which scope effects followed naturally.

Like Trabasso (Trabasso et al., 1971) and Clark (1976), Carpenter and Just used two related models, the constituent comparison and the constituent recoding models, to explain the different data patterns found in verification experiments. The constituent comparison model was considered the standard model, which could include a recoding operation, depending on the subject's strategy.

The representations used for the model are similar to Clark's, but differ somewhat in notation. They consist of predicates, written as *(predicate, argument)*, which can be denied or affirmed by an embedding proposition. Each proposition (or bracket) denotes one constituent. The full representation of a simple affirmative (29) or negative (30) sentence, for example, has two constituents. For this kind of statement, the negation (like the affirmation) has scope only over the inner predicate. Carpenter and Just called these narrow-scoped negative sentences predicate negatives. The model also allows for wider-scoped negatives, however (31). In this case, the negation has scope over the entire proposition *(aff, (dots, red))*. The width of scope has important implications for the duration of the constituent comparison stage.

(29) The dots are red.

(aff, (dots, red))

(30) The dots aren't red.

(neg,(dots, red))

(31) It isn't true that the dots are red.

(neg,(aff,(dots, red)))

According to the model, pictures are encoded affirmatively (i.e., with *aff*), but Carpenter and Just proposed to omit the affirmation marker for simplicity. Thus, the pictures could be encoded as simple predicates like *(dots, red)*. Since an *aff* marker is presumed to be equivalent to the absence of a marker, this should have no consequences for verification times.

At the comparison stage, the corresponding constituents of the two representations are extracted and compared, one pair at a time. The process starts with the innermost predicate and proceeds outwards (note the resemblance to Clark, 1976). If two constituents do not match, they are tagged and the entire process is reinitialized, i.e., it starts again with the first constituent. As a result of the tagging, the constituents will be treated as matches when re-encountered. The process stops when all constituents have been compared and matched. Verification times are a direct function of the number of constituent comparisons.

An important prediction from the model is that mismatches occurring in outer propositions have larger effects than mismatches in inner constituents. If a mismatch takes place at the innermost predicate, for example, only this first constituent has to be re-evaluated, adding only one extra comparison. By contrast, if the first two constituents match, and a mismatch occurs at the third step, all three constituents will have to be re-assessed, adding three extra comparisons. This explains how scope of negation can affect verification times. Negative markers always cause a mismatch, but for a wider-scoped negation this mismatch happens later, resulting in more additional comparisons.

Carpenter and Just tested the constituent comparison model in a paradigm that contrasted negations with wider and narrower scopes. Subjects were asked to compare sentences describing the color of dots with displays of 16 uniformly colored dots. The dots could be red, green, or black, and all three colors were used in all sentence types. Pictures and sentences were presented simultaneously. There were affirmatives, predicate negatives, and denials, such as (32), (33), and (34), respectively. In the representations of denials, Carpenter and Just omitted the *aff* marker of the third constituent, since it did not affect the truth-value of the sentence.

(32) It's true that the dots are red.
(aff, (red, dots))

(33) It's true that the dots aren't red.
(neg, (red, dots))

(34) It isn't true that the dots are red.
(neg, (aff, (dots, red)))

As in previous experiments, response times showed that TA were verified faster than FA, while FN were evaluated more quickly than TN. There was, however, an additional effect of negation type. Responses to denials were slower than responses to predicate negatives. In fact, while the ratio of negation time to falsification time was about 2:1 for predicate negatives, it was 4:1 for denials.

Given the representations that Carpenter and Just chose for the sentences (35), these results were predicted by the constituent comparison model. A TA (a) did not cause any mismatches, so only the basic two comparisons were executed. The predicate of a FA, however, conflicted with that of the picture, so that one extra step was necessary (b). Two extra comparisons were associated with false predicate negatives (c), since it was the second constituents that did not match. For true predicate negatives (d), a third extra comparison was added by the mismatch of the sentence predicate with the picture. Denials required two more comparison steps than predicate negatives because of the presence of third constituent with the *neg* marker; this resulted in four additional steps for false denials (e), and five for true denials (f).

(35)	*(red, dots)*	(picture)[6]	
	a. *(aff, (red, dots))*	(TA)	2 comparisons
	b. *(aff, (black, dots))*	(FA)	2+1
	c. *(neg, (red, dots))*	(false predicate negative)	2+2
	d. *(neg, (black, dots))*	(true predicate negative)	2+3
	e. *(neg, (aff, (red, dots)))*	(false denial)	2+4
	f. *(neg, (aff, (black, dots)))*	(true denial)	2+5

Carpenter and Just showed that the data for the six conditions lay approximately on a straight line when ordered according to the number of additional comparisons. A model with a single parameter for the duration of this comparison process accounted for 97.7% of the variance across the six means. When the model was applied to Clark and Chase's (1972) data, it could provide equally good fits, after Carpenter and Just inferred from the negation-to-falsification time ratio what kind of encoding subjects in those experiments had used.

The constituent recoding model is complemented by a recoding process, by which representations containing a *neg* marker could be transformed into affirmatives. This process consists in replacing *neg* with *aff*, and substituting the appropriate code within the predicate. Interestingly, recoding is thought to take almost exactly the same amount of time as the comparison operation. In further analogy to the comparison process, recoding is executed by repeatedly applying a substitution operation. Starting with the outer proposition, constituents are checked for the presence of the *neg* marker or the predicate. If either one of these elements

[6] The constituents that produced mismatches are underlined in the sentence representations.

is detected, it is converted (*neg* to *aff* and *black* to *red*, for example). Negations with a wider scope result in longer verification times because more constituents have to be searched until the predicate (the inner proposition) is found. Carpenter and Just applied the model to data from another of their own experiments as well as to results by Young and Chase (1971), Slobin (1964), and Gough (1965). Again, the fit was excellent.

There is, however, a problem with the model. Its predictions depend critically on the way statements are represented, and, as Tanenhaus and colleagues (Tanenhaus, Carroll, & Bever, 1976) pointed out, Carpenter and Just were not consistent in their choice of representation. In their first experiment, Carpenter and Just left out the third constituent, an embedding affirmation, for affirmatives (32) and predicate negatives (33). Carpenter and Just justified this with the fact that the presence of another *aff* marker would not change the truth-value of the statements. However, the presence of an outer proposition did influence the number of comparison operations that had to be executed. In fact, the difference between predicate negatives (33) and denials (34) is partly due to the presence of an outer proposition for the denial. Had all sentences been coded with three constituents, the difference between the two types of negative statements would consist of only one operation. Alternatively, all *aff* markers could have been omitted because they didn't affect truth-value. In either case, the data would not have fit the predictions following from these different representations (Tanenhaus et al., 1976). Yet, despite this and other criticisms (Caitlin & Jones, 1976), the model continued to be considered as a viable account of sentence verification (Shoben, 1978; Singer, 1977).

2.1.2.3 Pragmatic Accounts of Negation Difficulty

Despite their explanatory power and the elegance, the formal semantic models appear limited in their applicability. They seem to provide an account of the cognitive processes in a certain cognitive task, but they do not describe or explain how negation is understood and interpreted, and what effects it has on the processing of sentences outside a verification paradigm. These questions have been the focus of pragmatic approaches to negation. Some of these proposals have been aimed at explaining the difficulty of negation. They have done this by appealing to pragmatic constraints on the use of negation.

In fact, many of the pragmatic accounts have suggested that negative sentences are not inherently harder to understand than affirmative ones. It has been pointed out that negative statements are usually used to deny a suggestion or idea (Givón, 1979, 1984, 1989, 1993; Horn, 1989; Jespersen, 1917; Strawson, 1952). Consequently, it would not be surprising that negatives are harder to process when not used for their natural function and outside of an appropriate context (Cornish, 1971; Glenberg, Robertson, Jansen, & Johnson-Glenberg, 1999; Greene, 1970; Wason, 1965, 1971). A number of experiments have been carried out to demonstrate that the difficulty of negation can be alleviated or even eliminated if the experimental situation allows for the appropriate use of negative utterances.

Wason (1965) showed that the completion of negative statements could be facilitated in certain contexts. He proposed two related hypotheses about the contexts that would render the use of negation more appropriate. The 'exceptionality hypothesis' predicts that it is more plausible (and therefore easier) to deny that an exceptional item shares a property with the majority than it is to deny that a majority item has an attribute of the exceptional item. According to the 'ratio hypothesis', it should be easier to deny that a smaller set of items resembles the larger set than denying the opposite. Wason did not refer to the concept of supposition, but it is not difficult to see that the (presumably) more plausible contexts correspond to more plausible suppositions, namely that a given item belongs to or shares attributes with the majority.

The hypotheses were tested in similar paradigms, but two different groups of subjects. All subjects were shown arrays of eight dots, seven of which were of one color (red or blue) and one was of another color (blue or red, respectively). For the 'exceptionality' group, the circles were numbered. Subjects were first asked to describe the array aloud, so that the circles could be identified, e.g., "circle number 4 is blue and the rest are red". Then they were given an incomplete affirmative or negative statement, such as (36) or (37), and asked to name the corresponding color. The statements could refer to the exceptional circle or to one of the seven circles of equal color.

(36) Circle number 7 is …

(37) Circle number 4 is not …

In the 'ratio' condition, the circles were not numbered. Subjects first described the colors of the different sets of circles: e.g., "seven circles are red and one is blue". The statements they were asked to complete accordingly referred to these sets:

(38) Exactly one circle is …

(39) Exactly one circle is not …

(40) Exactly seven circles are …

(41) Exactly seven circles are not …

It was predicted that the difference in response time between affirmative and negative sentences would be smaller if the statement referred to an exceptional item or the smaller set. For the 'exceptionality hypothesis', this prediction was confirmed. While negative statements were always completed more slowly than affirmative sentences, this disadvantage was smaller for exceptional items. The 'ratio hypothesis', however, was not borne out. Wason attributed this to the fact that the subjects in this condition had to make initial descriptions that represented the sets as distinct and independent (Wason, 1965, 1971). Therefore, the smaller set was not perceived in relationship to the larger one. Since this relationship had been the basis for the hypothesis, it is not surprising that the prediction was not supported.

The 'exceptionality hypothesis' also was confirmed by de Villiers and Flusberg (1975). These authors adapted Wason's (1965) paradigm to be more appropriate for children because Donaldson's (1970) attempt to replicate the original study in five- and six-year-olds had failed. Instead of differently colored circles, de Villiers and Flusberg used sets of physical objects or drawings of objects in order to make it easier for pre-school children to deal with the task. Each set consisted of six or seven 'rule' objects of one kind and one exceptional item. In three of those sets, all objects came from a similar category (e.g., six horses and one cow) in the other three sets, they didn't (e.g., seven flowers and one shoe). This factor allowed them to test the additional hypothesis that confusability would increase the plausibility of negation. If all items were members of the same general category (e.g., animals), they could be more easily confused. It would consequently be more likely that someone would mistake the exceptional item as a 'rule' object.

During an experimental trial, the experimenter showed one of the sets to the child, pointed to an the object and asked the child "This is a …?" or "This is not a …?". For each set, a child was asked four questions, two referring to a 'rule' object and two referring to an exceptional object. The response times conformed to the exceptionality hypothesis: The difference between affirmatives and negatives was bigger for 'rule' than for exceptional items. In addition, the number of errors for 'rule' negatives was at least twice that for the exceptional negatives. Relatedness of the objects also influenced response times as predicted. The difference between exceptional negatives and exceptional affirmatives was smaller when the objects came from the same category and were therefore more confusable.

An experiment by Cornish (1971) provided further evidence for the role of pragmatic constraints on the use of negation. Cornish showed subjects pictures of a circle that was 7/8, 3/4 , 5/8 or 1/2 red (or blue) and instructed them to complete the fragment “The circle is not all…” by pressing the *blue* or the *red* button. For half the subjects, the circle was presented first, the other half saw the sentence fragment first. Cornish expected the subjects to complete the sentence more often with the color that occupied the larger part of the circle because the supposition that the entire circle was red should be more likely if more of the circle was red than blue. Consequently the denial of this supposition should be more appropriate. The frequency data showed a linear trend with *red* responses being most likely in the 7/8 *red* condition and least frequent in the 1/2 *red* condition. Response times (for appropriate answers) followed a similar pattern, although the trend did not reach significance for the subjects who saw the sentences first.

After the completion task was finished, a complete sentence like “The circle is not all red” was presented along with stimuli from the four conditions, and subjects were asked to rank the four circles according to how appropriate a description the sentence was for the picture. Cornish naturally predicted the same linear trend as in the other task: the sentence should be ranked higher as the proportion of red in the circle increased. The subjects’ rankings followed this prediction, lending support to the hypothesis that the appropriateness of negation depended on the match between the supposition and the state of affairs.

Greene (1970) took a related, but slightly different approach to explaining the processing cost of negation with pragmatic principles. She suggested that the natural function of negation was to signal a change in meaning, as it was used to deny an explicit or implicit assertion. Given an affirmation (42), its denial (43) is natural, since it changes the meaning of the statement. A negative statement is unnatural, by contrast, if it has the same meaning as the affirmative. Note that such a negative sentence (44) corresponds to a TN if the affirmative (42) is considered the state of affairs.

(42) x exceeds y

(43) x does not exceed y

(44) y does not exceed x

According to Greene's analysis, the comparison of affirmative and negative statements should be facilitated if negatives are used for their natural function, i.e., if the sentences differ in meaning. Passive sentences, by contrast, are thought to retain the meaning of the associated active sentence when used for their natural function. In the experiment designed to test this hypothesis, subjects were asked to decide whether a pair of sentences had the same or a different meaning. Affirmatives and negatives, active and passive sentences (e.g., (45) and (46), a 'natural' pair) as well as combinations (e.g. (46) and (47), an 'unnatural' pair) were used. The sentence pairs were printed on cards, and these cards were divided into packs of 'natural' and 'unnatural' pairs. The packs were handed to the subjects whose task it was to sort the cards into boxes with *same* and *different* labels according to whether the sentences had the same or different meanings.

(45) y exceeds x

(46) x is exceeded by y

(47) y is not exceeded by x

Greene predicted that subjects would take longer to sort the pack of 'unnatural' pairs. This was confirmed in all twelve subjects. The overall number of errors was rather small, but for negation pairs, the distribution was determined by the 'naturalness' of the pair: There were 14 errors on ‘unnatural’ pairs, but only one ‘natural’ pair was placed in the incorrect box. According to Greene (1970) and Wason (1971), these results provided evidence for the role of the natural function of negatives, even in a task where truth-values did not need to be assessed. This is not the only interpretation, however, since the comparison task is essentially equivalent to a verification paradigm. Hence, Clark (1976) applied the ‘true’ model to Greene’s results and explained the task in terms of propositional encoding and comparison.

Glenberg and colleagues (1999) showed more convincingly that negation effects could be found outside verification paradigms and, importantly, that these effects fade if the sentences appeared in an appropriate context. From Givón’s (1978) analysis of negation, it follows that isolated negative sentences are not informationally equivalent to affirmative ones. Negative sentences could be as easy to comprehend as affirmative ones, however, if they occur in a supportive context. The ostensible difficulty of negation should therefore be ascribed to the artificial nature of the verification paradigm.

In a first experiment, subjects were asked to rate the ambiguity of affirmative and negative statements about object attributes. The attributes were taken from the end point of a dimension, e.g., (48) and (49), or from a point closer to the middle of the dimension, e.g., (50) and (51). Subjects consistently rated negative sentences as more ambiguous. As they also judged mid-dimension affirmatives as more ambiguous than end-dimension affirmatives, subjects seemed to really consider the meanings and not blindly rate negative sentences as more ambiguous.

(48) The buttons are black.

(49) The buttons are not black.

(50) The buttons are darkly colored.

(51) The buttons are not darkly colored.

The second experiment demonstrated that negative sentences, although less informative in isolation, could be understood as fast as affirmative ones when their use was supported by the context. Subjects read short passages sentence by sentence. Each trial started with a neutral introductory sentence and one of two types of context: supportive or non-supportive. This context was followed by the critical sentence – a positive or affirmative statement – and a final sentence.

(52) i. She wasn't sure if a darkly colored couch would look best or a lighter color.
ii. She wasn't sure what kind of material she wanted the couch be made of.

a. The couch was black.
b. The couch wasn't black.

The critical sentence was a short descriptive statement like (52a,b). The supportive context mentioned a dimension that was relevant to the critical sentence and provided a supposition for the negation (i), while another dimension was used in the non-supportive context (ii). Subjects pressed a button after reading each sentence, so that the next sentence would appear. In order to make sure that subjects read the passages for meaning, subjects were prompted to type a few words about the content of the passage after having read the last sentence.

The dependent variable was the reading time for the critical sentence. There was a main effect of context and an interaction between context and negation. Overall, the critical sentences were read faster if they followed a supportive context. The effect of interest, however, was the interaction: while there was a significant effect of negation on reading times in the non-supportive context, the difference between negative and affirmative sentences was not significant after supportive sentences. This confirmed the hypothesis that negative sentences need not necessarily be more difficult than affirmatives ones. In fact, the difficulty of negation might be largely due to the use of sentences outside a supportive context.

Two experiments by Lüdtke and Kaup (2006) further examined what kinds of context are especially apt to facilitate negation processing. More specifically, they tested the hypothesis that the use of negation is most felicitous when it is used to deny a proposition that was either mentioned explicitly or rendered plausible by the context. As in Glenberg and colleagues' study (1999), the index of processing difficulty was the reading time for affirmative and negative target sentences that were preceded by different types of context. The first experiment contrasted contexts (53), in which the attribute to be affirmed or denied for an object in the target sentence (54), was explicitly mentioned (a,b) or not (c). When the relevant attribute was mentioned, it could be either the only possibility (a) or one of two options (b).

(53) On her way to the pool, Danielle wondered …
a. whether the water would be warm.
b. whether the water would be warm or cold.
c. what the water would be like.

(54) The water was (not) warm.

Reading times were consistenly longer for negative compared to affirmative sentences. The size of the negation effect, however, varied as a function of context, which was due to context-dependent changes in reading times for negative sentences only: When the denied attribute occurred in the preceding discourse (a,b), negative sentences were read faster than when the attribute was not mentioned (c). Affirmative sentences, by contrast, were read equally fast in all three conditions. Overall, the results were taken to suggest that the prior consideration of a proposition facilitated the processing of its negation.

Experiment 2 showed that negation associated difficulty could be eliminated alltogether if the negative sentence denied a proposition that was strongly implied by the discourse. Subjects in this experiment read stories that invited inferences about the state of an object, thereby creating more or less strong assumptions or expectations (55). The final sentence of the story always contradicted this expectation (56), but it was either affirmative (a) or negative (b).

(55) During the wedding reception, the kids of the guests were playing in the backyard of the hotel. Betty's young son was not shy and participated in any nonsense that the kids could come up with. Just before dinner, Betty summoned her son. She was going to change his clothes because she wanted him to look neat during the banquet.

(56) When here son came running up to her, Betty was astonished to see that his T-shirt…

a. was clean.

b. was not dirty.

For contexts such as (55), which induced strong inferences (as determined by prior norming), reading times for affirmative and negative sentences did not differ after adjustment for sentence length. This demonstrated that negative sentences need not be harder to process than affirmative ones if they are used for their natural function, that is, to deny a supposition, which in this case was derived from the discourse context.

Affective Connotations of Negation

Explanations of negation difficulty in terms of context and supposition have referred to the fact that denial is the typical function of negation in adult language. Developmentally, however, the first use of negation appears to be rejection. In addition, some of children's earliest experiences with negation are due to their parent's refusals or prohibitions (Pea, 1980a). It has therefore been suggested that it might be this association of negation with negative imperatives or prohibition that leads to the processing disadvantage of negative statements (Eifermann, 1961; Wason & Jones, 1963).

Eifermann (1961) exploited a property of Hebrew to show that the difficulty of negation might be due to its prohibitive associations. Hebrew uses two different negation markers, *lo* and *eyno*. *Lo*, like the English *not*, can be used in all contexts, including prohibitive ones. *Eyno*, by contrast, does not appear in prohibitive contexts. Thus, only *lo* could be associated with prohibition and negative affect.

The verification experiment included two groups of subjects: *lo* was used in one group, *eyno* in the other. Eifermann predicted that the effect of negation in a verification paradigm should be stronger when *lo* was employed. The results, however, did not reveal an interaction between sentence type (affirmative vs. negative) and negation marker. Indeed, negative sentences were verified more slowly in the *lo* group, but, for some unknown reason, the same was true for affirmative sentences in this group.

Wason and Jones (1963) chose a different experimental approach to the role of affective connotations in negation effects: they contrasted natural ('explicit') negation with what they called 'implicit' negation. For the 'explicit' group, regular sentences were used. In the 'implicit' group, assertion was expressed with the artificial marker *dax*, and denial was marked with *med*. As the artificial negation marker *med* could not have negative affective connotations, it was expected not to cause the same difficulty as regular negation with *not*.

The response times matched Wason and Jones's predictions. Negative sentences with *not* were verified significantly more slowly than affirmative sentences throughout the experiment, but this difference became minimal for *med* and *dax* during the second half of the study. The reduction of the negation effect was due to the response strategies that most subjects in the 'implicit' group adopted. These subjects did not interpret the statements, but formed decision rules like "if an even number and *dax*, or an odd number and *med*, then press *tick* [true]". The use of artificial affirmation and negation markers thus led the subjects to adopt different strategies. A change in strategy, however, merely shows that natural and artificial negation are different; it says nothing about the role of negative affective connotations (Clark, 1976). Thus, the prohibitive connotation hypothesis of negation difficulty failed to receive sufficient empirical support. It has not been pursued further.

2.1.2.4 Mental Simulation of Negative Statements

Usage-based approaches to negation have successfully demonstrated that the use of negation in pragmatically appropriate situations can significantly reduce or even eliminate processing difficulty. They have failed, however, to identify specific mechanisms or representations that produce the observed response time and error patterns, including the variable relationship between negation and truth value. Recently, Kaup (Kaup, 2006; Kaup, Zwaan, & Lüdtke, 2007) has proposed a new account that explains both classic verification results as well as pragmatic effects in terms of mental representations thought to underlie language processing. This account is founded on the mental simulation or experiential view of language comprehension, which posits that listeners mentally simulate the situation described by an utterance (e.g. Zwaan, 2004). This mental model or simulation is thought to be neither linguistic nor abstract propositional, but grounded in perception and action, that is, experiential in nature. In such a framework, it is impossible to explicitly represent negation, an inherently abstract linguistic or logical concept. Following Langacker's (1991) analysis of negation in terms of mental spaces (cf. Fauconnier, 1985), Kaup therefore suggested the *two-step simulation hypothesis*: Negation is encoded implicitly in the succession of two simulations, that of the expected state of affairs (which is being negated) and that of the actual situation. It resides in the discrepancy arising from a comparison of the two simulations, and the element being negated is the one that is present in the simulation of the expected, but not the actual situation. For example, comprehending the sentence (57) would involve a representation of Sam with a hat (a), followed by a representation of Sam without a hat (b). The hat being the only point of deviation between the two simulations, it would be recognized as the element to which negation applies. Support for the idea that the two simulations are activated successively has come from a series of experiments by Kaup and colleagues (Kaup, Lüdtke, & Zwaan, 2006, cf. section 2.2.2.1; Kaup, Yaxley, Madden, Zwaan, & Lüdtke, 2007, cf. section 2.2.2.3).

(57) Sam is not wearing a hat.

a. expected/negated state of affairs b. actual state of affairs

Understanding a negative sentence thus involves dealing with two mental simulations, while only one representation has to be constructed for an affirmative sentence. The two-step simulation hypothesis thus predicts that negative sentences should be harder to process than affirmatives – if they occur outside of a pragmatically appropriate context. However, if negatives are used to deny a supposition that was either explicitly mentioned or strongly implied in the preceding discourse, they should incur less difficulty: The simulation of the expected state of affairs is equivalent to the supposition to be denied, and since this supposition was available in the context, it should already be active or at least primed (Kaup, 2006; Kaup, Zwaan et al., 2007). For example, if prior to reading sentence (57), the comprehender was informed that Sam usually wore a hat whenever leaving the house, he might have inferred that Sam was wearing a hat in the current situation as well and mentally simulate this assumption (a). Upon encountering the denial (57), he might now only need to simulate the actual state of affairs (b). As a result, the comprehender would need less or no additional processing resources to deal with the negative sentence compared to an affirmative one.

In addition to explaining overall processing difficulty, the two-step simulation hypothesis can also account for the two response time patterns observed in sentence-picture verification paradigms. Like the semantic models, it posits that faster RTs are obtained when the representations of picture and sentence match. As negative sentence representations involve two different mental simulations, two different RT patterns can be observed depending on which of the sentence representations is involved.

(58) Picture: [$\genfrac{}{}{0pt}{}{\star}{+}$]

(59) The star is not above the plus. (FN)

a. negated state of affairs: ($\genfrac{}{}{0pt}{}{\star}{+}$)

b. actual state of affairs: ($\genfrac{}{}{0pt}{}{+}{\star}$)

(60) The plus is not above the star. (TN)

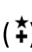
a. negated state of affairs: ($\genfrac{}{}{0pt}{}{+}{\star}$)

b. actual state of affairs: ($\genfrac{}{}{0pt}{}{\star}{+}$)

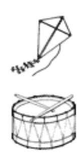
The first available simulation, i.e., the negated state of affairs (a), should be the basis for matching if the sentence is presented before or simultaneously with the picture (58). In this case, the representation associated with FN (59) will correspond to the picture, while the TN (60) will not. Consequently, FN will be verified faster than TN, producing the truth by negation interaction observed in experiments where subjects saw the picture before or at the same time as the sentence (Carpenter & Just, 1975; Clark & Chase, 1972; Trabasso et al., 1971).

A different outcome is expected when the sentence follows the picture with a certain delay. At this point in time, the subject should already focus on the actual state of affairs (b).

Now, the picture will fit the TN, which will lead to shorter response times than FN. That is, there will be a main effect of truth, as reported for paradigms in which the picture followed the sentence (Trabasso et al., 1971), especially when subjects were encouraged to focus on the actual state of affairs (Clark & Chase, 1972; Mathews, Hunt, & MacLeod, 1980), had high spatial abilities (MacLeod, Hunt, & Mathews, 1978), or became more practiced – and presumably faster – at doing so (Carpenter & Just, 1975).

Notwithstanding differences in the specific nature of sentence representations (experiential *vs*. propositional), the two-step simulation hypothesis and formal semantic models offer very similar explanations of the observed verification results: Both posit that the correspondence between sentence and picture representation determines response time patterns and that differences in the way the same sentence is represented are responsible for the differences in RT patterns. The two approaches involve not only different types of representations, however, but also different cognitive mechanisms that operate on these representations. According to the semantic models, sentence and picture representations are compared, and mismatches lead to increases in the time needed to complete the verification. The mental simulation approach, by contrast, does not include any comparison process. Instead, it suggests that one representation can prime another one, resulting in faster responses to the second stimulus. Thus, a picture of a star above a plus will be processed faster if the comprehender is currently focusing a representation of that situation (), which corresponds to the simulation of the actual state of affairs described by a TN (60). Conversely, a mental simulation of sentence content will be easier to construct if it is preceded by a picture matching the state of affairs to be simulated. That is, the simulation of the state of affairs negated by a FN (59) will be facilitated if it follows corresponding picture (58) with sufficient delay.

Given that the experiential simulation approach does not rely on comparison processes or the determination of truth values, the same negation effects that were observed in verification studies should be found in paradigms that do not require a verification decision. This was demonstrated in a study conducted by Kaup, Lüdtke, and Zwaan (2005). In this experiment, subjects read affirmative and negative sentences, all of which described the spatial relationship between two objects. Then, after a delay of 0 ms for one group of subjects and 1500 ms for the other group, subjects were presented a picture like (61). The pictures also contained two objects, and subjects were asked to decide whether the objects in the picture were the ones mentioned in the preceding sentence. When both pictures from the sentence also occurred in the picture, the depicted spatial could match that described in the sentence or not, but this was not relevant to the task. That is, a picture containing both of the objects from the sentence should always be accepted, regardless of the precise spatial configuration. In fact, all four example sentences (a)-(d) should lead to a positive response, despite their different truth values with respect to the picture.

(61) 

a. The kite is above the drum. (TA)

b. The drum is above the kite. (FA)

c. The kite isn’t above the drum. (FN)

d. The drum isn’t above the kite. (TN)

Kaup and colleagues predicted, however, that RTs to positive responses would be affected by the spatial configuration described in the sentence, as its simulation should prime the picture representation. The precise RT pattern was expected to depend on the delay between sentence and picture presentation. With no delay, subjects should still simulate the negated state of affairs for negative sentences, leading to shorter RTs to FN compared to TN. After 1500 ms, subjects should have shifted their attention to the actually described situation, with faster responses to TN than to FN.

In the 0 ms delay condition, the outcome of the experiment conformed to the predictions, as FN were verified faster than TN. At the 1500 ms delay, a different data pattern was found, but it was not the predicted one: Instead of longer RTs to TN than FN, as expected, there was no difference between TN and FN. Similar results had been found in classic verification studies (MacLeod et al., 1978: entire group; Roberts, Wood, & Gilmore, 1994), and it had been suggested that subjects could use different processing strategies leading to opposite RT profiles for negatives, so that the average pattern showed no significant difference between the two negative sentence types. Kaup and colleagues adopted a similar explanation for their findings. They conjectured that at least on a subset of trials some subjects were still focusing on the initial simulation of the negated state of affairs when the picture was presented, while others had already shifted attention to the representation of the actual situation. As the two simulations led to opposite results, the combination of both may have led to the total null effect for negatives. The two-step simulation hypothesis could thus accommodate the outcome of Kaup et al.’s (2005) experiment, and it could also be applied to earlier findings of similar RTs for TN and FN in verification studies (MacLeod et al., 1978; Roberts et al., 1994). Importantly, the different RT patterns were found outside of a verification paradigm, with a task that did not require the assessment of truth values or a comparison of the spatial relationships that turned out to affect RTs. Kaup’s account in terms of priming of one experiential process (picture recognition) by another (mental simulation) therefore appears preferable to an explanation based on a comparison of propositional representations and changes in truth value.

2.1.3 Summary

Negation has been found to cause processing difficulty in a number of experimental paradigms, but especially in those that require the assessment of a statement's truth-value. Three types of explanations have been proposed for this effect: syntactic, semantic, and pragmatic accounts.

The syntactic account of negation difficulty (e.g., Miller, 1962) attributes the difficulty of negative sentences to their transformational complexity. As this theory was tested in a number of experiments, it became clear, however, that it had to be dismissed because its predictions were not borne out, and there are better accounts (e.g., Gough, 1965; Slobin, 1966).

Semantic models of sentence verification (Carpenter & Just, 1975; Clark, 1976; Trabasso et al., 1971), by contrast, have accounted for a variety of experimental effects involving negation. They invoke a series of formal operations to explain not only the basic negation effect, but also the often-encountered interaction between truth-value and negativity as well as the absence of this interaction in certain paradigms. Besides accounting for verification data, however, these models may also help elucidate findings from other cognitive tasks. They propose rules for forming propositional representations that are not restricted to the verification paradigm. The errors made when recalling negative statements (e.g., Clark & Card, 1969; Cornish & Wason, 1970), for example, could be explained by the use of conversions during encoding or the loss of the outer (negating) proposition from memory.

Pragmatic approaches to negation, by contrast, have not focused on developing mechanistic accounts. Instead, they have criticized the formal accounts for neglecting the fact that negative sentences require a context that renders them meaningful and informative (e.g., Glenberg et al., 1999; Wason, 1971). Central to this approach is the well-established proposal that negation is typically used to deny suppositions (e.g., Givón, 1978; Horn, 1989; Strawson, 1952). Negation should be hard to process especially or only if not used for its natural function. Several experiments have produced data that are compatible with these claims. (e.g., Cornish, 1971; Greene, 1970; Wason, 1965).

The semantic models, however, can also account for much of these data (cf. Clark, 1976). Still, there are effects that the formal models are unlikely to explain. Examples are de Villiers and Flusberg's finding that the similarity between exceptional and rule items influences children's ability to use negation (de Villiers & Flusberg, 1975) or the fact that the reading times of negative sentences depend on the supportiveness of the context in which they appear (Glenberg et al., 1999; Lüdtke & Kaup, 2006). It is unclear how formal semantic processing models would apply to these studies, as the experimental manipulations do not match onto the representations or processes that the models include.

The explanatory power of pragmatic factors, however, also is limited. The interaction between negation and truth-value is unlikely to be explained by sentence context alone. Accounts in terms of the natural function of negation (e.g., Greene, 1970), likewise, do not speak to the effects of presentation order, and their predictions are overall less precise. In sum, both semantic and pragmatic theories have been successful at explaining negation effects, but neither one of them can account for all the data in the literature.

Kaup developed the two-step simulation hypothesis (Kaup, 2006; Kaup, Zwaan et al., 2007) to account for the entire body of data concerning negation. It proposes that processing negation involves two experiential representations of sentence content: a simulation of the negated (supposed) state of affairs, and one of the actual state of affairs. Overall processing difficulty, the interaction between truth and negation, effects of presentation timing, as well as the impact of pragmatic manipulations are explained in terms of these two kinds of simulations. The strength of the two-step simulation hypothesis is that it can explain the widest array of phenomena related to negation processing. Most of these explanations have been offered post-hoc, although there is some empirical support for the two-step simulation hypothesis in general (Kaup, Lüdtke, & Zwaan, 2006), and its application to processing difficulty in particular (Kaup et al., 2005).

2.2 Concept Activation and Interpretation

The effects of negation are not limited to cost or difficulty of processing. Negation clearly changes the meaning of a sentence, and the result is not simply a truth-value reversal. Negated expressions must somehow be reinterpreted, but the question is how precisely negation affects the processing of concepts within its scope. Psycholinguistic research has addressed a number of issues related to the interpretation of negation and negative quantifiers, which share pragmatic and syntactic properties with regular not-negation (cf. Klima, 1964; Sanford & Moxey, 2004). Experiments with quantifiers have demonstrated that negatives can direct the focus of attention and influence how reference is resolved (e.g., Sanford & Moxey, 2004). Other studies have investigated how negation impacts the activation of a concept, and whether a concept's construal is actually reversed or just modified by negation (e.g., Giora et al., 2004; MacDonald & Just, 1989). The results have been conflicting, and it appears that the effects depend on the context in which the negated expression occurs (e.g., Giora, 2006; Giora, Fein, Aschkenazi, & Alkabets-Zlozover, 2007) as well as the time at which an effect is probed (e.g., Hasson & Glucksberg, 2006; Kaup, 2001).

2.2.1 Quantifier Effects

Quantifiers are used to introduce subsets of elements into a discourse. The size of this subset can vary, and quantifiers are used to express how large it is. Yet, quantifiers not only differ in the amount, i.e., the quantity that they refer to. They also have a polarity, which is not directly tied to the amount they denote. *A few*, for example, is a positive quantifier, while *few* or *not quite all* are considered to be negative quantifiers. It is believed that the difference between the two lies in the negative property of denial. A positive quantifier asserts the size of a subset, while a negative quantifier denies that the set is as large or larger than a certain quantity (Moxey, Sanford, & Dawydiak, 2001; Sanford, Williams, & Fay, 2001).

Negativity and the associated property of denial play an important role in the meaning and the effect of quantifiers in discourse processing (Moxey & Sanford, 1993; Sanford & Moxey, 2004). Moxey, Sanford, and associates have extensively studied how quantifier polarity determines which subset becomes the focus of attention (Moxey et al., 2001; Paterson, Sanford, Moxey, & Dawydiak, 1998; Sanford, Moxey, & Paterson, 1996). According to their findings, positive quantifiers, such as *some* in (62), focus on the reference set, i.e., the set that is described in the sentence. So in the example, the reference set would include the fans that went to the game. By contrast, negative quantifiers like *few* in (63) tend to direct the attentional focus to the complement set, containing those elements for which the sentence predicate is false. For (63), the fans that did not go to the game would be focused.

(62) Some of the football fans went to the game.

(63) Few of the football fans went to the game.

Focused elements are more accessible, so they are preferred referents for subsequently occurring pronouns (Sanford & Garrod, 1989). This fact has been useful in the investigation of the focus patterns associated with different quantifiers.

Sanford, Moxey, and Paterson (1996) examined the of positive and negative quantifiers in a sentence production task. They presented sentences like (62) and (63) to subjects and asked them to generate a subsequent sentence, which made sense starting with the pronoun "They…". The responses were rated by three independent judges according to whether they referred to the reference or the complement set.

Five positive (*nearly all*, *almost all*, *more than half*, *many, a few*) and five negative (*not quite all*, *not all*, *less than half*, *not many, few*) quantifiers were used, and according to pretests, both sets of quantifiers spanned denotations from about 10% to 95%. Despite the equal distribution of quantity denotations, the focus preferences differed between positive and negative quantifiers. While positive quantifiers almost exclusively resulted in reference-set completions, the majority of the completions following negative quantifiers referred to the complement set. There were no significant differences within each set of quantifiers.

A further analysis of the sentence completions revealed that negative quantifiers tended to lead to explanations of why the predicate was not true for the expected number of individuals. No such reason-for-why-not characterized the completions following positive quantifiers; rather, a number of reasons-for-why completions were encountered.

Moxey, Sanford, and Dawydiak (2001; Sanford & Moxey, 2004) proposed the inference theory of complement focus to account for both the focus patterns and the reasons-why-not completions. The basis of the theory is the denial aspect of negativity (cf. Horn, 1989). Negative quantifiers are thought to deny a supposition, and this denial leads the reader to search for reasons why the supposition was not fulfilled. Consequently, the processing focus is directed to the subset that does not fit the supposition, i.e., the complement set.

Evidence for the relationship between denial and complement set focus was found in other continuation production experiments, similar to that by Sanford et al. (1996). The quantifiers used in one study were first submitted to a pretest for denial according to Klima's (1964) negativity diagnostics. Subjects were asked to decide for sentences like (64) which tag would fit the sentence better. Three pairs of affirmative and denying tags were used: *neither*/*so*, *do they*/*don't they?*, and *either*/*too*. *Few* and *not quite all* were received more denial ratings, while *at most 10%* and *at most 90%* received predominantly affirmative tags.

(64) *Q*[7] of the men were happy, and neither/so is Mary.

The continuations were totally unconstrained, i.e., no sentence beginning was given to the subjects. As a result, relatively few pronominal references were used. The pronominal references that were employed, however, followed the pattern predicted by the inference theory: denial quantifiers led to complement set references more often than to affirmative quantifiers. The same was true for reasons-why-not completions. Similar data patterns were found in a second experiment with different quantifiers and constrained continuations (beginning with "They…" or "…because they…").

The inference theory was tested by Sanford, Williams, and Fay (2001), in a more direct way, that dispensed with subjective judgments of referents. The method was based on the *including* relation, which maps individuals to sets, such as in (65).

(65) *Q* of the students had a car, and that includes Sophie.

(66) Did Sophie have a car?

If the quantifier focused the referent set, the predicate should apply to the included individual; the predicate was false, however, for an individual included in the complement set. The response to (66) therefore indicated which set was focused.

[7] In the actual sentences, *Q* was replaced by a quantifier.

For each of the quantifiers in the study, a denial index was computed based on pretests. This index corresponded to the percentage of judgments in favor of denying tags according to the procedure of Moxey and colleagues (2001). The denial index for the negative quantifiers not many, few, and *no more than 10%* ranged from .98 to .40. For the positive quantifiers at most 10%, a few, and at least 10%, these values lay between .02 and .10. As in the previous studies using the continuation methodology, complement set references were significantly more frequent for negative (denying) quantifiers.

If readers indeed direct their focus to the set that is implied by a quantifier, a subsequent sentence that is inconsistent with this focus pattern should be associated with increased processing cost. Sanford and colleagues (1996) tested this implication in a self-paced reading task. They presented a quantified sentence like (67) followed by a critical sentence that referred to the reference (a) or to the complement (b) set.

(67) *Q* of the MPs attended the meeting.

a. Their presence helped the meeting run smoothly.

b. Their absence helped the meeting run smoothly.

Whole sentences were displayed one at a time, and the reading time to the critical sentences was recorded. The results were consonant with those of previous studies. After positive quantifiers, reading times were shorter for sentences with reference set reference. Negative quantifiers, by contrast, facilitated the reading of subsequent sentences with complement set reference. A similar reading time study with *including* relations (Sanford et al., 2001) reported the same data pattern.

The empirical evidence thus has substantiated the focus effects associated with quantifier polarity. There is, however, an asymmetry in the strength of these associations. Positive quantifiers focus almost exclusively the reference set. The complement set focus of negative quantifiers, by contrast, is prevailing, but it is by no means exclusive. Negative quantifiers appear to *license* complement set focus, but they do not block reference set focus (Moxey et al., 2001; Sanford et al., 1996; Sanford et al., 2001). This may be due to the inferential nature of complement set focus. According to the inference theory, complement set focus is the result of the search for reasons why the denied supposition was not met. Not only is this more involved a process than the automatic activation of the reference set upon encounter of the quantified statement, it is also likely to consume more time.

Paterson et al. (1998) hypothesized in accordance with the inference theory that the complement set did not become available immediately as the quantified noun phrase was read. Instead it would be inferred later during the integration of the anaphoric sentence. To test this prediction, Paterson and colleagues conducted a reading study in which the time-course of the different focus effects was assessed by means of eye-tracking. In one of their experiments, they had subjects read sentences like (68). *Few* and *a few* were used as quantifiers, and the continuation after the causal connective *so* referred either to the referent set or the complement set.

(68) *Q* of the men were careful/careless with their winnings, so **|** they gambled recklessly **|** until the money was gone.[8]

The eye-tracking results indeed showed different focus effects for the two quantifiers. After both *a few* and *few*, more time was spent on the initial reading of the zone including the pronoun if the phrase referred to the complement set (e.g., when *careful* been used in the quantified sentence) irrespective of the quantifier. The total time spent on reading the clause after *so*, however, showed a violation effect for both quantifiers. For *a few*, reading was slowed

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[8] The limits of zones for the eye-tracking analysis are indicated by **|** .

with complement set reference, and for *few*, reading took more time with reference set reference.

These results could be easily explained by the inference account. Initially, the reference set was focused automatically irrespective of the quantifier, so that a reference to the complement set increased reading time. During further processing, the complement set could be inferred following *few*, so that at this point mismatches in both directions could be detected.

The inference theory of complement focus has proposed a further role for the pragmatics of negation. The use of negatives to deny a supposition has been invoked to explain the referential focus pattern associated with negative quantifiers. The applicability of the concepts of denial and supposition thus extends beyond verification data. In fact, these notions have helped address questions about the interpretation of negative sentences and the establishment of discourse reference.

2.2.2 Suppression vs. Retention

Negation clearly changes the meaning of a statement. To achieve this, it must somehow affect the sentence and discourse representations that are the basis for interpretation and meaning construction. The question is how negation impacts the representations within its scope. A negated concept may, for example, be suppressed, such that it becomes less accessible (e.g., MacDonald & Just, 1989); or it can be retained but with a modified interpretation (e.g., Giora et al., 2004). Likewise, there are different possibilities as to how the interpretation is affected. The negated concept may be recoded into the opposite of the original concept (Mayo, Schul, & Burnstein, 2004), or it may merely be mitigated while retaining the original meaning (e.g., Giora et al., 2004). While these two questions are not completely identical, they are strongly related. Therefore, we will consider them in conjunction.

2.2.2.1 Suppression and Recoding

Negation, when employed in a sentence like "No representative showed up for the meeting", is used to deny that the sentence predicate applies to the negated concept. The quantifier studies have shown that the originally introduced referents become less accessible as a result of the denial, and, if the negative is a quantifier, the complement set is focused (e.g., Sanford & Moxey, 2004). That is, attention is directed away from the elements in the scope of negation, and they become less accessible. According to De Mey (1971), this effect applies not only to negative quantifiers, but negation in general. He suggested that negation acts as a correcting device, shifting attention by suppressing an activated element and allowing an alternate to be activated as a result

MacDonald and Just (1989) proposed a very similar hypothesis. Based on their intuitions that negation decreased the relative prominence of the negated concept and shifted the focus away from it, they argued that the activation level of a concept was lowered by a negative; the concept would be inhibited. They tested this hypothesis in three related experiments.

The same kinds of sentence materials were used in all the experiments. Each sentence contained two object nouns, and the first (69), the second (70), or neither (71) of the objects was negated.

(69) Almost every weekend, Elizabeth bakes no bread but only cookies for the children.

(70) Almost every weekend, Elizabeth bakes some bread but no cookies for the children.

(71) Almost every weekend, Elizabeth bakes some bread and some cookies for the children.

For stimulus presentation, the moving-window technique was used: the screen showed dashes representing the sentence, and subjects pressed a button to move the reading window to a new word. After the sentence, a probe word appeared. The general prediction was that responses to probes would be slower if the probe was related to the negated concept.

In the first experiment, subjects were asked to verify whether the probe had appeared in the sentence. The probe could be the negated or the affirmed noun or a word that was not part of the sentence. Consistent with the prediction, response times were slower for nouns that had been negated in the sentence. An equivalent data pattern was found in experiment 2, in which subjects named the probes.

In the third experiment, subjects again named the probes, half of which were associates of the nouns in the preceding sentences and half of which were the nouns themselves. For the words from the sentences, the negation effect was replicated. For the associates, however, the effect did not reach significance, although the data pattern was the same as in the other tasks. MacDonald and Just reasoned that the small number of items used in this condition might be responsible for the lack of significance.

Overall, the results confirmed MacDonald and Just's hypothesis. Negated concepts were associated with longer response times, likely due to their decreased accessibility. Negation appears to have inhibitory effects at the level of sentence or discourse representation.

Kaup (Kaup, 1997, 2001, 2006; Kaup & Zwaan, 2003; Kaup, Zwaan et al., 2007) has questioned that explicit negation was the only explanation for the observed increase in response times. She has suggested that in MacDonald and Just's sentences, negation not (only) affected the level of propositional representations. Instead, the negated concepts were absent from the experiential simulation or situation model (Glenberg, Meyer, & Lindem, 1987; van Dijk & Kintsch, 1983; Zwaan, 2004) of the sentence content. In a sentence like (72), by contrast, the negated concept (photographs) would be present while the non-negated one (letters) would be absent.

(72) She burned the old letters but not the photographs.

If the accessibility of concepts is uniquely dependent on their presence in the situation model, then a reverse negation effect should be found for sentences like (72). Alternatively, it is possible that both negation and presence in the situation model impact response times.

Kaup tested these hypotheses in a paradigm similar to that used by MacDonald and Just's experiment 1. However, she presented entire passages sentence-by-sentence, and the critical sentences depicted either creation situations like (69) through (71) or destruction situations like (72). An interaction between negation and situation type was expected. There should be a strong negation effect with the negated noun being verified more slowly than the non-negated noun for creation sentences. For destruction sentences, by contrast, this negation effect should be reduced or even reversed, as the non-negated noun would not be a part of the situation model. An analysis of several experiments by Kaup (1997, 2001) showed main effects for both negation and situation type as well as the predicted interaction. At the same time, the results revealed, however, that explicit negation was the dominant factor in determining concept availability. Negation effects had the same direction for both creation and destruction situations, but they were smaller in destruction situations.

Given that both sentence form and presence in the situation model appeared to have effects on concept accessibility, Kaup and Zwaan (Kaup, 2001; Kaup & Zwaan, 2003) reasoned that both types of information were represented separately. The sentence representation with the explicit negation marker should be constructed first, while the situation model should take longer to form (cf. Schmalhofer & Glavanov, 1986). If this was the case, then negation effects would be detectable earlier, while situation model effects would appear later.

Kaup and Zwaan (2003) used different sentence materials to examine the time-course of accessibility effects, although they had the same logic: negation and presence in the situation were crossed. Explicit negation was used in two sentences, e.g., (74) and (76). The concept *pink dress* was absent in the situation models corresponding to one affirmative and one negative sentence, e.g., (75) and (76) respectively, and present in the models for one affirmative and one negative sentence, e.g., (73) and (74) respectively.

(73) Sam was relieved that Laura was wearing her pink dress.

(74) San wished that Laura was not wearing her pink dress.

(75) San wished that Laura was wearing her pink dress.

(76) Sam was relieved that Laura was not wearing her pink dress.

Two separate experiments were conducted with these materials. In the first experiment, probe words (e.g., *pink*) appeared 500 ms after the offset of the critical sentence. In experiment 2, the delay was 1500 ms. As predicted, there was a significant negation effect in the short-delay experiment, but no effect of presence. The interaction numerically resembled that found in Kaup's previous experiments (Kaup, 1997, 2001), but it was not significant. Also in correspondence with Kaup and Zwaan's expectation, there was a significant presence effect in the long-delay experiment, but the negation effect was reduced and non significant.

Kaup and Zwaan's findings showed that explicit negation alone did not determine the accessibility of a concept. Nonetheless, they simultaneously provided further evidence for the availability reducing effect of negation. According to De Mey (1971), negation acts on accessibility by directing attention away from one concept, with another one getting activated instead. For negative quantifiers, Sanford and Moxey (2004) have shown that the attention is shifted from the reference set to the complement set. For other negated sentences, the situation is less clear, as there is not always a counterpart available.

Kaup's two-step simulation hypothesis posits that negation involves shifting the attentional focus from a representation of the negated state affairs to one of the actual state of affairs. As the actual state of affairs can often not be inferred from the given informaiton (e.g. *Sara didn't wear the red dress* leaves unclear what Sara was wearing instead), the simulation can remain underspecified with respect to the element that is affected by negation (Kaup, Zwaan et al., 2007). In this case, it is uncertain what would become focused or activated instead of the negated item. It is possible that other elements of the sentence or discourse become more prominent, but this option has not been tested so far.

The actual state of affairs can be fully specified if there is a unique alternative that can replace the negated concept, that is, when there were only two options, one of which is being denied in the negative sentence. If the appropriate inference is made, the non-negated alternative can replace the negated item in the simulation. When the concept that is being denied is an adjective, a direct opposite is often available. Many adjectives are organized in polar pairs of antonyms like *hot* vs. *cold* or *dead* vs. *alive*. Thus, negated polar adjectives could be represented as their polar contraries, with a meaning opposite to that of the original adjective. That this can happen spontaneously has been demonstrated by Trabasso and colleagues (1971) in a verification paradigm and by Cornish and Wason (1970) for sentence recall.

Additionally, an experiment by Kaup, Lüdtke, and Zwaan (2006) provided more direct evidence for a recoding of this kind. Subjects in this study read affirmative and negative sentences that described the state of an object using pairs of opposing adjectives (77).

(77) *Sentence*

The umbrella was closed.

The umbrella was not open.

(78) *Picture*

a. actual state b. alternate/negated state

When a picture of the object (78) was presented 1500 ms after the offset of a negative sentence, it was named faster if the object was shown in the actual state described in the picture (a) compared to depiction of the negated state (b). Picture processing (and naming) appeared to be facilitated by a matching internal representation of the object. Kaup and colleagues concluded that 1500 ms after reading a negative sentence, subjects were simulating the actual state of affairs, which included the object in the state opposite to the one denoted by the negated adjective. Negated adjectives can thus be recoded into their polar opposite, depending on the availability of such a concept (cf. section 2.2.2.3: Mayo et al., 2004).

2.2.2.2 Retention and Mitigation

There is a logical problem with the hypothesis that negation is used to reverse the meaning of a statement or concept; it confounds contrary and contradictory opposition (cf. Horn, 1989). A meaning reversal corresponds to the activation of the polar opposite, i.e., the contrary of the original concept. *Cold*, for instance, is the contrary of *hot*. Negation, by contrast, is used to deny, i.e., to contradict that a certain state of affairs is true – without entailing the truth of the polar opposite. The statement “My drink is not hot” does not entail that my drink is cold. It simply implies that my drink is less than hot, which could be cold, but also merely warm. The contrary is thus only one possible alternative to the negated concept.

Giora, in fact, has suggested that the interpretation of a negated concept can often be closer to the original concept than to its opposite (Giora, 1995; Giora et al., 2004; Giora et al., 2005). This follows from her retention hypothesis of negation, according to which a negated concept is retained and not disposed of. The apparent suppression of negated concepts (e.g., MacDonald & Just, 1989), would therefore not be obligatory or automatic, although it can occur if appropriate for a given utterance.

The retention hypothesis leads to a view of the interpretation of negation that Giora calls mitigation (Giora et al., 2004; Giora et al., 2005). In pragmatics, mitigation has been defined as the modification of a speech act: a softening of or a reduction in the force of an utterance in order to prevent potential offense or other unwelcome effects (Fraser, 1980). Giora has borrowed the term to describe the effects of negation on a statement within its scope. The idea is that negation results in a weakened or toned-down version of the affirmative without reversing its core meaning.

Several experiments by Giora and her associates have substantiated her claims about the retention of negated concepts and the mitigating effect of negation (Giora et al., 2004). One experiment tested the effect of negation on the priming of associates. According to the retention hypothesis, a concept should prime its associates irrespective of whether it is affirmed or negated.

In three sentences, an object was described with a polar adjective (79), the same adjective negated (80), and its antonym (81).

(79) The instrument is sharp.

(80) The instrument is not sharp.

(81) The instrument is blunt.

Sentences were presented as a whole, and subjects pressed a key when they finished reading a sentence. A probe appeared 100 ms after the offset of the sentence, to which subjects were asked to make a lexical decision. The probe was either a word related to the first adjective (e.g., *piercing*), an unrelated word (e.g., *leaving*) or a non-word.

As predicted, both the affirmed and the negated adjectives were associated with a significant priming effect (difference in lexical decision time between the related and the unrelated probe). In addition, the effect did not differ between the two conditions; it was numerically identical. No priming was found for antonyms. These results provided support not only for the retention hypothesis, but also for the Giora's graded salience hypothesis (Giora, 2003), according to which lexical access is not influenced by contextual factors, including negation.

Lüdtke and colleagues (Lüdtke, Friedrich, De Filippis, & Kaup, 2005) reported similar results, as they failed to find evidence for reduced activation of negated concepts in their event-related potentials (ERP) experiment. They had subjects read sentences that either affirmed or denied the presence of an object in a particular situation (82).

(82) 

a. In front of the tower there was a ghost.

b. In front of the tower there was a lion.

c. In front of the tower there was no ghost.

d. In front of the tower there was no lion.

After a 250 ms or a 1500 ms delay, the sentence was followed by a picture that contained the object whose presence was under discussion (a,c) or another object (b,d). Additionally, the picture could be consistent (a,d) or inconsistent (b,c) with the sentence, depending on whether the sentence was affirmative (a,b) or negative (c,d). The dependent variable was the N400, an ERP component whose amplitude decreases if a stimulus is primed (e.g., Bentin, McCarthy, & Wood, 1985), time-locked to the picture. If negation decreased the activation of the sentence-final word (or concept), it should also reduce the extent to which the word would prime the picture. That is, if a negated concept was inhibited, it should prime the picture less than its non-negated version; the N400 to the picture should be larger for FN (c) than for TA (a). No such effect was found however. The N400 to the target picture was smaller if the sentence contained the target word compared to sentences ending with an unrelated word. Negation made no difference, and the experiment did not support the hypothesis that negated concepts are suppressed.

The retention hypothesis states that the meaning of a negated concept is retained to participate in the construal of the intended meaning. Negation is expected to have a modifying, not a suppressing effect; the interpretation of a negated polar adjective should therefore differ from that of the adjective's antonym. This prediction was tested in an additional experiment by Giora (2004). Subjects were asked to rate short sentences with adjectives on a scale describing the dimension to which the adjective belonged. The scale comprised 7 points, with 1 denoting the negative and 7 the positive pole. Positive and negative adjectives were chosen and used in sentence pairs. One sentence contained a non-negated adjective (83), the other its negated antonym (84). Subjects always saw one pair at a time, and rated it on the appropriate scale.

(83) The vegetables looked fresh.

(84) The vegetables looked not rotten.

The ratings clearly showed that subjects did not interpret the negated items as their antonyms, which would have corresponded to suppression and meaning reversal. Instead, subjects rated the negated concepts as falling approximately in the middle of the scale, with only a slight tendency toward the antonym. This effect was similar for negative and positive adjectives. The retention hypothesis has thus also been corroborated with respect to the interpretation of negated concepts; their core meaning appears to be retained, albeit mitigated by the use of negation.

This view of negation as mitigation has recently been extended to the case of negative irony (Giora et al., 2005). According to Giora (1995), irony involves a significant gap between what is said and what is referred to, such as the overstatement in (85a). The wider the gap, the more obvious the irony (Colston & O'Brien, 2000). The negation as mitigation view predicts that a negated overstatement like (b) should still be perceived as ironic, because it doesn't close the gap, but merely narrows it. Likewise, a negated non-overstatement like (c) would further narrow the gap, resulting in reduced but still perceivable ironicity. By contrast, the opposite of the overstatement (d), merely describes reality, and should not be considered ironic.

(85) Although Max was working very hard preparing for his exams, he failed them all.
a. Max is exceptionally bright.
b. Max is not exceptionally bright.
c. Max is not bright.
d. Max is stupid.

Subjects were therefore asked to rate the ironicity of sentences like (85) on a scale from 1 (*non-ironic*) to 7 (*highly ironic*). Different subsets of the materials were used in two experiments. The first experiment demonstrated the reduction of ironicity due to negation: subjects judged affirmative overstatements (a) as most ironic, negative overstatements (b) as less ironic, and negated non-overstatements (c) received an even lower ironicity score. Experiment 2 tested the hypothesis that negation did not eliminate irony. Again, affirmative overstatements (a) were rated more ironic than negated overstatements (b). Importantly, both types of overstatements had higher ironicity scores than the opposite of the affirmative (d), confirming the prediction of the negation as mitigation view.

The retention hypothesis has thus been supported by empirical findings showing that the meaning of a concept is retained despite negation and that negation modifies, but does not reverse a concept's interpretation. Giora (2004) has taken this as evidence against proposals in which negation reduces concept accessibility. In fact, the retention hypothesis was formulated to directly contradict the suppression view of negation. The suppression view, however, has also been substantiated by experimental results (Kaup, 2001; MacDonald & Just, 1989). The question thus arises as to how to reconcile these contradictory findings and hypotheses.

2.2.2.3 Mediating Factors: The Context of Negation

The proponents of the suppression hypothesis of negation have not made direct predictions regarding the impact of negation on the interpretation of concepts. We have argued, however, that their position is compatible with the idea that negation reverses the meaning of a concept. Giora, in fact, has claimed that this view follows from the suppression hypothesis (Giora et al., 2005). She also has presented evidence against meaning reversal and for the retention of meaning, albeit in mitigated form (Giora et al., 2004; Giora et al., 2005). Yet, other studies have shown that the interpretation of negated concepts is not uniform across contexts and lexical items. Depending on semantic factors and pragmatic constraints, interpretations of negated adjectives can seem to include the contrary as well as a toned-down version of the original meaning (Colston, 1999; Mayo et al., 2004).

Mayo, Schul, and Burnstein (2004) have suggested two different models for the encoding of a negative message and compared their applicability to different concepts. According to the schema-and-tag model, which resembles Giora's retention hypothesis, a negated concept (e.g., *not tidy*) is represented as a core meaning and a negative tag (*neg[tidy]*). The fusion model, by contrast, predicts meaning reversal. It asserts that the negated concept is transformed and encoded as the contrary of the negated core meaning (*messy*).

In addition, Mayo and her associates have proposed that the accessibility of a contrary might determine which encoding model is applied. A contrary is more easily available when the negated adjective is part of a bi-polar scale (e.g., *tidy* vs. *messy*). The fusion model should therefore be applicable. For uni-polar adjectives whose opposite is usually defined as the absence of the core property (e.g., *charismatic*), a genuine contrary should be less accessible. Thus, the schema-and-tag model is more likely to be used.

These predictions were tested in an experiment that assessed what kind of associations would be primed by negated messages containing these two kinds of adjectives. It was based on the idea that the different representations corresponding to the two models would facilitate different associations. A negated uni-polar adjective should be encoded according to the schema-and-tag model. The core meaning (e.g., *charismatic*) would therefore be retained and activate its semantic associates (e.g., *charm*). The interpretation of a bi-polar adjective (e.g., *tidy*) would be reversed (to *messy*) according to the fusion model. Thus, associations with the contrary (e.g., *clutter*) should become more accessible.

Ten bi-polar and 10 uni-polar adjectives were used in affirmative and negative descriptions of a person (86i and ii, respectively). Each sentence was presented on a screen, and once the subject pressed a button, it was replaced by a probe. The probe sentence was either congruent (i-a and ii-b) or incongruent (i-b and ii-a) with the description, or it was irrelevant (c). Subjects were asked to judge whether the probe was congruent with the description.

(86) i. Tom is a tidy person.
ii. Tom is not a tidy person.

a. Tom's clothes are folded neatly in his closet.

b. Tom forgets where he left his car keys.

c. Tom likes to have long conversations on the phone.

Response times to the probes were analyzed for effects of congruency, negation, and adjective type. For uni-polar adjectives, there was an interaction between negation and congruency. Following affirmative statements, congruent probes (i-a) were assessed more quickly than incongruent ones (i-b). Probes following negative descriptions, by contrast, were judged faster if they were incongruent with the message but corresponded to what was being denied (ii-a). This was predicted by the schema-and-tag model according to which the core meaning of the negated concept was retained. The same associations (a) were facilitated by affirmative and negative statements, since the same concept was represented. Yet, if the description contained a bi-polar adjective, faster response times were elicited by congruent probes, irrespective of whether the first sentence was affirmative or negative (i-a and ii-b). That is, affirmative and negative descriptions activated different associations, corresponding to the sentence message. Negated sentences were encoded in the opposite schema, as predicted by the fusion model. Mayo and colleagues thus demonstrated that the interpretation of a negated concept is, at least partly, determined by semantic properties of the lexical item, namely the availability of a well-defined opposite.

Colston (1999) pointed to various pragmatic factors that may influence the meaning of negated expressions. He suggested that expectations about the outcome of an event affect how a negatively phrased description of the event is interpreted. The theoretical bases of his proposal are Relevance theory (Sperber & Wilson, 1986) and verbal politeness (Brown & Levinson, 1987).

Relevance theory contends that interpretations, or contextual effects, are the result of interaction between the content of an utterance and background knowledge, or contextual assumptions. If an utterance is very precise, the impact of contextual assumptions is limited. More indirect statements, by contrast, require contextual assumptions for successful interpretation. Negative statements are indirect, and rather uninformative (Leech, 1983). Their interpretation should therefore hinge more on background knowledge, for example about the expected outcome of an event.

Based on this reasoning, Colston argues that negation should have asymmetric effects on positively and negatively valued terms, depending on whether the term agrees with the expectation or not. If an event is expected to turn out good, for instance, a description of this event as *not good* disconfirms the expectation, making the alternative interpretation *bad* available. *Not bad* would neither confirm nor disconfirm the interpretation, and should therefore be interpreted as *neither good nor bad*. Generally speaking, the denial of the expectation is construed as equivalent to the contrary of the expectation, while the denial of the contrary is interpreted as occupying a middle ground. No differences between positive and negative expectations are predicted.

Verbal politeness as a theoretical construct adds to the relevance theoretic account a positivity bias that can override contextual effects. The positivity bias describes people's tendency to speak in a socially positive manner. One expression of the bias is the avoidance of negative terms (e.g., *ugly*, *rotten*) in favor of negated positive ones (e.g., *not pretty*, *not fresh*). Negated positive terms should therefore be ascribed a negative meaning. Without consideration of verbal politeness, the relevance theoretic analysis predicts that negated positive terms are interpreted as lying between good and bad. If verbal politeness takes priority, however, the negated positive terms will receive a negative interpretation. The asymmetry described above would therefore not apply if a negative outcome is expected.

Colston's account is supported by results from a study in which participants judged affirmative and negated statements on a polar scale. Subjects were presented with short scenarios whose outcome could reasonably be expected to be good or bad, such as (87) and (88), respectively. The scenario was followed by an affirmative negative (a), a negated negative (b), an affirmative positive (c) or a negated positive (d) comment on the outcome of the event. Subjects were asked to rate the outcome descriptions on a scale from 1 to 7 (e.g., *ugly* vs. *pretty* and *mad* vs. *happy*).

(87) Fawn bought a print at an art store for her room. When asked how she liked it, her roommate Maxine replied,

a. It's ugly.
b. It's not ugly.
c. It's pretty.
d. It's not pretty.

(88) Kim had to tell her father that she had wrecked his car. Her boyfriend asked her how that went and she said,

a. He was mad.
b. He was not mad.
c. He was happy.
d. He was not happy.

For scenarios that suggested a positive outcome (87), the judgments conformed to an asymmetric pattern: Direct negatives (a) and negated positives (d) were rated equally negative. Direct positives (c) were judged most positive, and negated negatives (b) lay in between the two poles. This was predicted by the relevance account of negation. Verbal politeness did not matter in this case, as the negated positives were interpreted as negative with or without positivity bias.

When a negative outcome was expected (88), a symmetric rating pattern was found. The negative pole was occupied by direct negatives (a) and negated positives (d). Direct positives (c) and negated negatives (b) were rated equally close to the positive end of the scale. Verbal politeness was taken to explain this latter finding, as the relevance theoretic account alone predicted the negated negative to be rated as less positive than the direct positive.

Whether or not Colston's specific model is correct, the experimental results demonstrate that negated adjectives can be interpreted differently in different contexts. Sometimes, the interpretations resemble the predictions of the meaning reversal view; in other circumstances, they agree with the negation-as-mitigation proposal. Depending on contextual and lexical factors, a reversed or mitigated meaning can be constructed for a negated concept. Considering these along with Mayo et al.'s (2004) findings, it seems that a uniform account of negation interpretation is rather unlikely. To some extent, this is not surprising: the semantic models of sentence verification (e.g., Clark, 1976) already offered two alternative ways for encoding negated statements, and there was evidence for the spontaneous application of both (Trabasso et al., 1971). As Clark suggested, the 'true' method (or the schema-plus-tag model) may be more generally applicable, but given appropriate lexical items and a supportive context, the 'conversion' (or fusion) model is sometimes used.

The availability of an opposite thus appears to be a prerequisite for the recoding or conversion of negated concepts. A possible reason for this is that the opposite serves as a readily available alternative on which attention is focused as it is directed away from the negated item (*cf*. De Mey, 1971). The same reasoning can be applied to the more general question of whether negated information becomes less activated and accessible. Perhaps a negated concept only becomes less activated if another piece of information is available to be focused on instead.

Indeed, suppression effects of negation have usually been found when there was a counterpart of some kind to the negated item. Both MacDonald and Just (1989) and Kaup (1997, 2001) used sentences with two nouns, only one of which was negated. In this situation, the negated noun may have been less activated because attention was directed away from it to the non-negated one. In terms of Kaup's two step simulation hypothesis (Kaup, 2006; Kaup, Zwaan et al., 2007), the simulation of the actual state of affairs contained only one object, the non-negated one, which received all the available activation. So the non-negated noun was named faster than the negated one.

The experiment by Kaup, Lüdtke, and Zwaan (2006) was similar to Mayo and colleagues' (2004) study in that it employed adjectives. Kaup et al. used only adjectes that were organized in pairs of opposites. Thus, when a certain state was denied for an object, subjects could easily infer that the opposite state was likely to apply and focus on (or simulate) that situation. Consequently, subjects responded faster to pictures related to the inferred (opposite) state than to pictures depicting the negated state. Mayo et al.'s results can thus also be explained in terms of an attention shifts and the resulting changes in activation level. For negated adjectives with polar opposites, focus was directed away from the negated property to its opposite, which resulted in the faster responses to sentences consistent with the opposite compared to the negated attribute. No alternative was readily available, however, for negated adjectives without an opposite, so that the focus of attention remained on the negated item.

Similarly, Kaup, Lüdtke, and Burkert (2006) failed to find negation effects when employing negative sentences that denied the presence of an object without mentioning any alternative objects that might be present instead. In another study, Kaup, Yaxley, Madden, Lüdtke, and Zwaan (2007) also used sentences describing a situation that had no unambiguous alternative or opposite – with the same results. Subjects in the epxeriment first read the sentence and then saw a picture and decided whether the depicted object had occurred in the sentence (89, 90). The sentences placed (or didn't place) the object in a certain location, which had implications for the shape of the objects (e.g., open wings for an eagle in the sky; closed wings for an eagle in the nest). On target trials, the picture contained the correct object in one of two possible shapes (a-b).

(89) The eagle was (not) in the sky.

a.  b. 

(90) The eagle was (not) in the nest.

a.  b. 

The same picture (a) led to faster responses for affirmative and negative sentences; its shape matched the situation location asserted in the affirmative and denied in the negative sentence. The absence of a negation effects indicates that the object representations were unaffected by negation, presumably because the denial of one location did not allow for a clear inference as to the actual location and shape of the object. There was no alternative to simulate.

In addition to the availability of an opposite or alternative, Giora (Giora, 2006, 2007; Giora et al., 2007) has argued that that global discourse considerations must be taken into consideration. She has suggested that while suppression may be the default strategy, it may not apply if the negated information is necessary to establish coherence with the preceding or following discourse. When negative sentences are presented out of context (e.g., Hasson & Glucksberg, 2006; MacDonald & Just, 1989), the default strategy applies, and negated concepts are suppressed. When occurring in a wider context, however, both affirmative and negative information should only be discarded if a change in discourse topic is signalled (cf. Gernsbacher, 1990). As a rule, global discourse requirements should dominate local cues like negation, as evidenced by Kaup and Zwaan's (2003) finding that, after a 1500 ms delay, the presence of an object in the situation determined concept availability, irrespective of negation. In sum, it appears that both local context, such as the availability of an alternative to the negated item, as well as global discourse, like the need to establish coherence, will determine whether a negated concept will become less accessible and another one activated instead.

2.2.3 Time-Course of Negation Effects

The context in which the negative phrases occur determines to a considerable extent whether negation effects can be found in a particular experimental setting. Another, so far unmentioned variable is the precise point in time at which effects are probed. The experiments described so far have used different delays between the occurrence of the negation and the probe point, and they have found different effects, which, to some extent, can be explained by differences in timing combined with specific task demands and context variables.

2.2.3.1 Post-Sentential Effects

All the negation effects reported so far were measured after the end of the sentence (or clause) containing the negated element. The quantifier induced set focus changes were either tested in off-line rating experiments (Moxey et al., 2001; Sanford et al., 1996; Sanford et al.,

2001) or, when on-line methods were used, they occurred only in the next sentence (Sanford et al., 1996) or clause (Paterson et al., 1998). Recoding or mitigation effects, too, were assessed in rating (Colston, 1999; Giora et al., 2004; Giora et al., 2005) and response time (Kaup, Lüdtke, & Zwaan, 2006; Mayo et al., 2004) experiments exclusively after the end of the negative sentence. Finally, probes for the testing of suppression effects were also presented some time after the offset of the negative sentence (Giora et al., 2004; Kaup, Lüdtke, & Burkert, 2006; MacDonald & Just, 1989) and sometimes even after another intervening sentence (Kaup, 2001). In sum, all negation effects on concept activation have been observed quite late after the occurrence of the negation marker.

How late an effect is probed, however, appears to have a significant impact on whether it can be detected. All other things being equal, the sooner an accessibility effect has been tested, the lower the probability of finding suppression. At the same time, the task being used in the experiment may be more or less sensitive to negation. Overall, it seems that priming paradigms are less likely to produce (early) negation effects than tasks that require responses to the negated word itself (i.e., word naming or presence verification). In addition, context plays an important role, as properties of the stimulus material may facilitate or hinder the emergence of inhibitory negation effects. MacDonald and Just (1989), for instance, found suppression effects in word naming and presence verification paradigms with probe words placed immediately after the offset of the target sentence. Besides the task, this may have been due to the fact that the stimuli were particularly conducive to a negation induced attention shift, as the sentences always mentioned two objects, only one of which was negated, so that non-negated noun became the primary focus of attention. Giora et al. (2004) failed to find an inhibitory effect in a priming task with a very short delay between sentence and probe of 100 ms. They used adjectives with polar opposites, which in principle could serve as alternative. The retrieval of the opposite, however, appears more effortful than a simple redirection of attention to material mentioned in the same sentence, as was necessary in MacDonald and Just (1989). Thus, no negation effect could be detected with such a short ISI. Kaup and colleagues (2007) did not even find any negation effects after 250 ms. Their materials, however, lacked not only explicitly mentioned alternatives, they also did not afford inferences as to an alternative. The focus of attention therefore remained on the negated concept, at least for as long as 250 ms. At a 500 ms delay, however, Kaup and Zwaan (2003) were able to detect negation effects with similarly difficult materials, due perhaps to the slightly longer delay but probably also to the use of a presence verification task instead of a priming paradigm.

In order to track the time-course of negation effects more reliably, the same materials have to be used in the same task, but with variable probe points. This has been realized in an experiment by Hasson and Glucksberg (2006) as well as the earlier mentioned study by Kaup, Lüdtke, and Zwaan (2006). These studies have in fact demonstrated that negation effects may emerge over time, as suppression or recoding effects could be detected only at later probe points. Hasson and Glucksberg (2006) presented affirmative and negative metaphors (91) followed by a lexical decision probe word.

(91) Some surgeons are/aren't butchers.
a. affirmative-related probe[9]: clumsy
b. negative-related probe: precise

They chose metaphors in order to avoid purely lexical priming effects between the final word and the probe, so that any priming could be ascribed to the meaning derived from

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[9] For negative metaphors, the affirmative-related probe was related to the negated as opposed to the actual negative meaning of the metaphor.

metaphor comprehension. Probe words on experimental trials were either related to the affirmative (a) or the negative (b) meaning of the metaphor or unrelated controls. Affirmative-related probes should be accepted faster if subjects were representing the affirmative meaning of the metaphor, and the negative-related probes should be primed by a representation of the negative meaning.

The probes were presented to different subjects at different delays after the offset of the sentence: 150 ms, 500 ms, and 1000 ms, as Hasson and Glucksberg hypothesized that negation effects might develop over time. The data corroborated this hypothesis. At the two earlier intervals, there was no effect of negation: The affirmative-related probe was facilitated by both the affirmative and the negative metaphor, and the negative-related probe received no priming from either. After 1000 ms, however, the affirmative-related probe was facilitated only after an affirmative metaphor, which was taken as evidence that the affirmative meaning had been suppressed. The negative-related probe again was not primed in either condition. Hasson and Glucksberg thus concluded that the negated (affirmative) meaning of a negative metaphor was inhibited sometime between 500 and 1000 ms after the sentence had been read.

Evidence for the activation of the alternative (negative) meaning, however, was only found after the metaphors were sorted into groups according to the extent that they were perceived to be ironic by a different group of subjects. It was the group of low-irony metaphors (e.g., *Some workers are not robots*.) that showed this effect: Negative metaphors initially primed the affirmative-related probe, but at the 1000 ms delay, only the negative-related word was facilitated. Both types of high-irony metaphors (e.g., *Her marriage wasn't an anchor.*), didn't prime either probe at the 100 ms delay, but facilitated only the affirmative-related probe later.

The authors attributed this to the possibility that meaning construction may take longer for high-irony metaphors, and that reversal effects might be found at even longer delays.

Kaup, Lüdtke, and Zwaan (2006) found similar changes in negation effects over time. As we reported earlier (*cf*. section 2.2.2.1), pictures related to the actual state of affairs described by negative sentences were processes faster than those related to the negated state of affairs. At a shorter delay of 750 ms, however, subjects responded to both pictures equally fast. Kaup and colleagues adopted the same explanation they provided for a similar effect in another study (Kaup et al., 2005): Some subjects were (on some trials) still representing the negated state of affairs, while others had shifted to the actual situation, which resulted in the overall null effect. This is a rather plausible account given that the actual state of affairs eventually dominated, while the negated state of affairs had been found to be more active at shorter delays in other experiments (e.g., Kaup et al., 2005; Kaup, Zwaan et al., 2007). In any case, the experiment demonstrated that negation effects become stronger over time.

In fact, what appears to develop over time is a representation of the actual state of affairs, including negation as well as other information provided by the discourse. Kaup and Zwaan's (2003; cf. section 2.2.2.1) study on the effects of negation and situation presence is a case in point: At 500 ms after the offset of the target sentence, there was a reliable effect of negation, but whether an object was present in the situation had no additional effect. At a delay of 1500 ms, however, the presence in the situation, which was determined both by the specific semantics of the verb as well as negation, determined the result pattern. Also consistent with this idea is Kaup's (1999, 2001) finding of situation presence effects in addition to negation effects after an even longer delay.

In sum, negation effects tend to develop over time. Evidence of suppression can be found very early after sentence offset, however, if negation is used in a context that affords an easy shift in attention or change in representation as well as a facilitative task. After about 1000 ms, suppressive negation effects can be measured in most paradigms, and at longer delays concept activation is determined by the interaction of negation and other contextual variables.

2.2.3.2 Intra-Sentential Effects

The main issue addressed by the studies of post-sentential negation effects concerned the effect negation has on the representation of different parts of the sentence. A different question is to what extent negation can affect the initial processing of upcoming elements in the same sentence. If the negation marker is integrated into the incremental sentence representation, it should also have an impact on how subsequent information is processed within the negative sentence. By changing the semantic context in which a subsequently received word will be integrated, negation should affect how well the word fits within this context. In fact, it should even influence a person's expectations about upcoming lexical items (for arguments concerning on-line prediction see DeLong, Urbach, & Kutas, 2005; van Berkum, Brown, Zwitserlood, Kooijman, & Hagoort, 2005; Wicha, Moreno, & Kutas, 2004; for off-line data on negation-induced expectation changes see Appendix D).

The impact of negation on semantic context could take two forms. Negation could change the incremental interpretation of the sentence in a way that makes a different lexical item more likely to occur or easier to integrate. Alternatively (or simultaneously), negation could merely reduce the degree of sentential constraint. For the affirmative fragment "The capital of France is…", for example, only one possible completion can be reasonably expected. The corresponding negative fragment has hundreds of possible endings. Thus, the effects of negation can be qualitative, changing the most expected ending, or quantitative, decreasing sentence constraint. Besides the nature of the negation effect, its time-course is of interest as well. Studies of negation effects on concept activation to date have reported only late effects, so the question is whether negation can effect expectations and semantic fit more immediately, sooner after the occurrence of the negation marker.

A component of the event-related potential (ERP), the N400, has been shown to vary as a function of semantic context and sentential constraint. Although not only elicited by words, but also other potentially meaningful stimuli, the N400 has been used extensively to study sentence processing at the level of meaning. The amplitude of the N400 correlates with the semantic fit of a word within a context, with highly expected words eliciting smaller N400s than less expected ones (Kutas & Hillyard, 1980, 1984).

If negation makes a word incongruous for a given sentence, or merely less probable (since other words would be plausible, too), these changes should be reflected in N400 amplitude. Two studies used these properties of the N400 to study the effect of negation on the processing of semantic relationships (Fischler et al., 1983; Kounios & Holcomb, 1992). No effects of negation on N400 amplitude were found. Only response times to a verification task proved sensitive to the changes in meaning and truth-value that were due to negation.

Fischler and colleagues (1983) presented “class inclusion” statements, such as (92) through (95), and asked subjects to verify the sentences. Each of these statements began with a concrete noun (e.g., *a robin*) and ended with a superordinate category name (e.g., *a bird*). The two nouns were connected either by *is*, or *is not*, yielding affirmative or negative sentences, respectively. In addition to statement form, the relationship between the concrete noun and the category was varied: the concrete noun was either an exemplar of the category or not. The truth-value of the sentence thus depended on the combination of category relationship and statement forms. An affirmative statement was true when the first noun was a member of the category (92) and false when it was not (93). Negative sentences, by contrast, were true when the concrete noun was not a category member (95), and false when it was (94).

(92)	A robin is a bird.	(TA)
(93)	A robin is a vehicle.	(FA)
(94)	A robin is not a bird.	(FN)
(95)	A robin is not a vehicle.	(TN)

The dependent variable was the N400 amplitude to the final word, the category name. Since it directly followed the negation marker in negative sentences, any N400 difference would have provided evidence for immediate negation effects. If subjects had updated their expectation about the category name based on the occurrence of a negation marker, the N400 to the final word would have been greater in (94) than in (92). The results, however, showed no such effect. The N400 was determined exclusively by the relationship between the first and the second noun, in both affirmative and negative sentences. That is, if *robin* was the sentence subject, the N400 to *vehicle* was larger than that to *bird*, irrespective of whether the word made the sentence true or false. While the ERPs did not appear to be sensitive to truth-value or negation, verification times showed the expected interaction between the two factors. Thus, subjects obviously processed the negation, but its effect were limited to late (post-N400) interpretive processes. Fischler et al. explained the lack of a negation effect on N400 with reference to Clark’s (1976) model of sentence verification. According to this proposal, the positive inner proposition (corresponding to the supposition) was computed first and therefore reflected in the N400. The outer negation entered processing later, so that its effects could only be detected in response times.

Kounios and Holcomb (1992) also failed to find effects of negation on N400 amplitude, although the delay between the negative quantifier and the critical word was longer in their experiment. Each sentence contained an exemplar and a category term that were either related (96, 97) or not (98, 99), but half the sentences started with the exemplar (96, 98), the other half with the category (97, 99). The sentence subjects were quantified with *all*, *some*, or *no*, which resulted in a complicated pattern of truth-values.

(96) *Q* rubies are gems.

(97) *Q* gems are rubies.

(98) *Q* spruces are gems.

(99) *Q* gems are spruces.

Truth-values or the type of quantifier, however, did not have any effect on the N400 elicited by the predicates (the sentence-final nouns). Instead, N400 amplitude was modulated by the relationship between the two nouns as well as their ordering. Negation (here in the form of quantification) did neither produce a main effect nor did it interact with the other factors. Only verification latencies were affected by quantifier type. Thus, not only negation, but other types of logical distinctions failed to produce early effects.

Both ERP experiments described here suggest that the time-course of negation processing is protracted. No evidence for an influence of negation on intra-sentential processing has been found by these studies nor by any other study reviewed in this paper. Instead, negation has been found to impact later verification processes, which probably do not reflect initial comprehension processes (cf. Tanenhaus et al., 1976). Yet, negation does not just affect inferential or interpretative processes. It has also been shown to have effects on the processing of subsequent information (Mayo et al., 2004; Paterson et al., 1998). These studies, however, have tested these effects only in the sentence or clause that followed the negated statement. In the ERP studies (Fischler et al., 1983; Kounios & Holcomb, 1992), which allowed for the detection of early processing differences, however, no negation effect was found. The empirical evidence so far would seem to imply a protracted time-course of negation processing and a considerably delayed impact of negation on contextual constraint. This, however, would bestow upon negation a special status, setting it apart from other sources of context variation. Indeed, substantial evidence favors incrementality, i.e., the use of many forms of information as soon as it becomes available (e.g., Kamide, Altmann et al., 2003).

Hypothesis

There may be reasons for Fischler's (1983) and Kounios and Holcomb's (1992) failure to decect intra-sentential negation effects: Both studies used isolated sentences, and the pairs of nouns were either very strongly related (e.g., *robin* and *bird*), or completely unrelated (e.g., *robin* and *vehicle*). Given this, the observed data pattern is not surprising if one takes into account what is known about the pragmatics of negation as well as contextual influences on lexical activation. A consideration of the possible effects of negation on expectations may help to see why this might matter. Negation effects can be thought of as context effects that facilitate or hamper the processing of upcoming lexical items.

In the two ERP experiments under discussion, negation produced neither facilitation nor inhibition. One possible explanation for the lack of inhibition is the strong association between the first and the second noun. According to some models of lexical access (Duffy, Morris, & Rayner, 1988; Giora, 2003), context cannot block the activation of the most salient meaning of a concept. By analogy, it may be impossible to inhibit an association as integral to a concept's meaning as that between a category and one of its typical members. Thus, it may be hard if not impossible to find an effect of negation on the processing of such strong categorical relationships.

Pragmatic constraints on the use of negation provide another reason for the absence of an inhibitory effect on the related noun. Negation is typically used to deny a supposition, and in the absence of further discourse context, this supposition must be grounded in general knowledge. That is, in isolation negation is used to deny something that is part of an invoked schema (Fillmore, 1985). The isolated experimental sentences evoke the schema associated with the first noun (e.g., *robin*). Consequently, only elements of that schema (e.g., *bird*) can be denied, and they should therefore be *expected* completions of the negative (as well as the affirmative) sentence. By contrast, unrelated items (e.g., *vehicle*) do not constitute acceptable completions. They are not part of any invoked schema, and given their unrelatedness it is unlikely that someone might have mistaken, for example, a *robin* for an instance of a *vehicle*. Thus, these unrelated endings should not be expected or facilitated – just as the experimental data showed.

It seems thus unlikely that negation effects can be detected when sentences are used outside of context. These isolated negative sentences can only deny stereotypical facts or assumptions – the same information and lexical items that are associated with the affirmative sentence. As a result, the expected completions are indistinguishable. In order to detect effects of negation on expectations about upcoming words, it appears therefore necessary to embed experimental sentences in wider contexs – contexts that can provide suppositions or possibilities that can be denied plausibly and that are independent of stereotypical associations which seem to affect negative and affirmative sentences equally.

CHAPTER 3

NEGATION IN A CONTEXT OF CHOICE

The primary goal of this dissertation was to test the hypothesis that negation has effects on the processing of subsequent words within the same sentence or clause. This hypothesis implies that the negation marker is integrated into the sentence on-line – as opposed to earlier proposals according to which negation is not considered until after the affirmative inner proposition has been processed (Carpenter & Just, 1975; Clark, 1976; Fischler et al., 1983).

At the end of Chapter 2, we have argued that, in order to detect such early negation effects in an experimental setting, it may be necessary to embed the negative sentences in a context that provides suppositions that can be plausibly denied. The experiments in this dissertation have therefore employed choice scenarios such as Example (1-3).

(1) *Introduction*

During his long flight Joe needed a snack. The flight attendant could only offer him pretzels and cookies.

(2) *Affirmative bias*

a. Joe wanted something salty.

b. Joe wanted something sweet.

(3) *Target sentence*

i. So he bought the pretzels.

ii. So he bought the cookies.

iii. So he didn’t buy the pretzels.

iv. So he didn’t buy the cookies.

All stories were constructed according to the same pattern: The first two sentences (1) introduced the options a character had to choose from. The following bias sentence (2), which in this first set of experiments was always affirmative, provided information about the preferences of the character. Finally, the target sentence (3) presented the outcome, i.e. the character's choice. The target sentence could be affirmative or negative, and its final word was one of the two options that were introduced in the beginning of the story. In both the affirmative and negative case, the correct ending (which made the final sentence consistent with the preceding information) was unequivocally predictable, as both options had been presented earlier, and favoring one (e.g., *salty* implied *pretzels*) was equivalent to excluding the other (i.e. not *cookies*). These stimuli thus differed importantly from those used in previous ERP experiments (Fischler et al., 1983; Luedtke, De Filippis, Friedrich, & Kaup, 2005), where no clear prediction was possible for negative sentences.

3.1 Experiment 1a: Event-Related Potentials

The primary experimental support of the view that negation is considered only after the processing of the embedded affirmative proposition has come from Fischler and colleagues' (1983) ERP experiment. In this study, the N400 to the sentence-final word was the main variable of interest: As its amplitude was independent of the presence of a negation marker in the sentence, Fischler inferred that the negation had not yet been processed. Experiment 1a was designed to refute Fischler's findings and conclusions. To do this, choice scenarios like Example (1-3) were used in a verification paradigm, where the final sentence could be consistent or inconsistent ('true' or 'false') [10] with the rest of the story as a function of both the sentence mode –affirmative or negative– and the final word. Just like in Fischler's experiment, the consistency or truth could thus only be determined upon perception of the final word. The N400 to this final word was therefore the primary dependent variable in the current experiment, as well.

Fischler and colleagues took the N400 to reflect a process of monitoring the consistency or validity of propositions. Although few researchers at present would subscribe to this particular functional interpretation, the N400 is a good indicator of how plausible or expected a word is within (or at the end of) a given sentence. In fact, it has been shown that the N400 is sensitive to the match between a word and its context at different levels: lexical associations, sentence, and discourse constraints. The N400 to a word is reduced in amplitude when that word is preceded by a semantically related lexical item. This priming effect has been observed for word lists (Bentin et al., 1985) as well as for word pairs embedded in sentences (Van Petten, Weckerly, McIsaac, & Kutas, 1997). Besides these lexical relationships, N400 amplitude depends on the fit between a word and the overall sentence meaning (e.g. Van Petten et al., 1997). When a word is a good fit or highly expected in a sentence context, it elicits a smaller N400 than a less expected or less well fitting word (DeLong et al., 2005; Federmeier, Wlotko, De Ochoa-Ewald, & Kutas, 2007; Friederici, Pfeifer, & Hahne, 1993; Hagoort & Brown, 2000; Kuperberg et al., 2003; Kutas & Hillyard, 1984). The global discourse-context in which a sentence is embedded provides further constraints that can affect the N400. Words that fit equally well in an isolated sentence (e.g., *Fortunately, I didn't lose all my files/friends*.) will elicit smaller N400s if they are

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[10] To maintain continuity with prior research in this area, the term *truth* will be used when describing the experiments in this dissertation, although strictly speaking, the factor of interest is not the truth value, but the consistency of a sentence in the story.

consistent with the wider discourse context (i.e., *files* in *My computer system suddenly broke down.*), and larger N400s if they violate the discourse constraints (Salmon & Pratt, 2002; van Berkum, Hagoort, & Brown, 1999; van Berkum, Zwitserlood, Hagoort, & Brown, 2003). The N400 is thus sensitive to different forms of semantic context: lexical associations as well as sentence and discourse constraints.

In the current experiment, both the lexical and the message level were manipulated and expected to affect N400 amplitude. At the lexical level, final words (such as *pretzels*) that were related to the bias sentence (…*salty*.) should be facilitated and elicit a smaller N400 compared to unrelated final words (*cookies*). At the same time, the presence or absence of negation changed the sentence and discourse constraints, as it determined the consistency (or truth) of the final word and sentence with the story. A final sentence ending in *pretzels*, for instance, was consistent with the bias sentence *He wanted something salty*. (2a) in its affirmative form (3i), but not if it was negative (3iii).

(2) *Affirmative bias*

a. Joe wanted something salty.

(3) *Target sentence*

i. So he bought the pretzels. (TA)

ii. So he bought the cookies. (FA)

iii. So he didn't buy the pretzels. (FN)

iv. So he didn't buy the cookies. (TN)

The N400 to the final word should therefore not only depend on that word's relatedness to the bias sentence, but also on the (affirmative or negative) mode of the sentence – if negation had already been integrated into the sentence representation. If this was not the case, one would expect the results to parallel Fischler's, with small N400 to related endings (TA and FN) and large N400s to unrelated endings (FA and TN). If however negation was already part of the sentence representation and could therefore affect expectations, as hypothesized, a different, more complex result pattern should emerge. In this case, the smallest N400 should be observed to TA (3i) as they were both related to the bias and true. Being both unrelated and false, FA (3ii) should elicit the largest N400. The two negative sentences should lead to N400s lying between these two extremes, as each received facilitation from only one of the two sources truth and relatedness: FN (3iii) were related, but false, while TN (3iv) were unrelated, but true. The ordering of FN and TN would depend on the relative strength of the truth and relatedness effects: If truth was more important than relatedness, then TN should elicit smaller N400s than FN; if relatedness had a stronger effect, the opposite order should be found.

In addition to the N400, a late positive component (LPC) was also expected to vary as a function of sentence truth. The LPC is a form of the P3, a domain-general component that is elicited by unexpected task-relevant stimuli (Duncan-Johnson & Donchin, 1977) and that has been suggested to reflect event categorization (Kok, 2001) or the updating of working memory representations as a function of newly received information (Donchin & Coles, 1988). P3-like positivities to complex stimuli in higher cognitive tasks such as language processing are usually referred to as LPC or P600 (although their membership in the P3 family is contested if they are elicited by a syntactic manipulation: see Kutas, Federmeier, Staab, & Kluender, 2007). LPCs have been observed in response to semantic or pragmatic anomalies, following an N400 in some cases (Faustmann, Murdoch, Finnigan, & Copland, 2005; Münte, Heinze, Matzke, Wieringa, & Johannes, 1998). One could therefore expect to observe a larger LPC to false compared to true sentences in the current experiment, in particular because of the use of a verification decision, which made the truth of the sentence highly task relevant.

Even before the final word, negation effects might be found on the verb of the target sentence, which in the negative modality was preceded by the negative contraction *didn't*. If the negation marker was immediately integrated into the sentence representation and possibly used to change expectations about the sentence continuation, signs of these processes might be visible in the ERPs to any of the words following the negation. Lüdtke and colleagues (2005), for example, observed a sustained negativity on the word following the German negation marker *kein/e* (*no*) compared to the same words in the affirmative sentence version. Fischler et al. (1983) also observed a slight negativity toward the end of the ERP to the negative *is not* compared to the affirmative *is* frame, although the difference was not further analyzed. We therefore planned to test for the presence of negation effects, namely a (sustained) negativity, in the ERP to the target sentence verb.

The ERP data were complemented by a number of behavioral measures. Response times and accuracy were recorded to compare the result pattern with the ERP findings. Although no absolute match to the N400 pattern, the RTs in Fischler et al. (1983) also showed a significant truth x negation interaction: TN lead to longer RTs than FN, paralleling the N400 findings. If the current experimental setup would indeed reveal negation effects in the ERP, one would expect to find similar changes in the RT results. Accuracy was expected to be high overall as it was emphasized over speed in the instructions. If effects were found, they should parallel the RT pattern, as is typical for verification studies.

Finally, we administered a Stroop test (Stroop, 1935), a measure of inhibition or cognitive control, as well as two tests of print exposure, which correlate with linguistic ability (Stanovich, West, & Harrison, 1995). The purpose of these tests was to collect data on individual differences in overall cognitive and linguistic aptitude, which might help explain potential variability in the ERP and RT results.

3.1.1 Method

3.1.1.1 Subjects

Thirty-two subjects (19 women) with a mean age of 20.1 years (range 18-24 years) participated for academic credit or a cash payment of $7/hour. All were right-handed native speakers of English with normal or corrected to normal vision and no history of neurological disorders.

3.1.1.2 Design and Materials

<u>Tests</u>

Handedness was assessed with the Edinburgh handedness inventory (Oldfield, 1971). Version 4 of Stanovich and West's Author and Magazine Recognition Tests (Stanovich et al., 1995) was used to assess print exposure. For the Stroop test, two test sheets were created: one with colored strings of four Xs, one with color words. Each sheet contained 60 strings, arranged in four columns. Four ink colors – red, green, blue, and pink – were used, each fifteen times per sheet. The neutral version contained the strings of Xs printed in the different colors. In the interference condition, the same four color words appeared, always printed in an ink color that did not match the word. All word-ink combinations occurred equally often. See Appendix B for samples of all testing materials.

Table 3-1. Sample stimuli for Experiment Set 1 (affirmative bias). All bias-target combinations and the resulting experimental sentence types are shown.

		During his long flight Joe needed a snack. The flight attendant could only offer him pretzels and cookies. Joe wanted something…	
		salty.	sweet.
So he bought the…	pretzels.	True Affirmative (TA)	False Affirmative (FA)
	cookies.	False Affirmative (FA)	True Affirmative (TA)
So he didn't buy the…	pretzels.	False Negative (FN)	True Negative (TN)
	cookies.	True Negative (TN)	False Negative (FN)

Experimental Stimuli

One-hundred-twenty scenarios such as Example (1-3), consisting of a two-sentence introduction, a bias, and a target sentence, were created. The introduction always remained the same, but there were two different versions of the bias and four versions of the target sentence. Each subject saw all 120 scenarios (with the same two introductory sentences), but different subjects saw different versions of the bias and target sentences. The two versions of the bias each referred to one of the two previously introduced options. One version of each scenario was assigned to one of two lists. For the target sentence, there were two affirmative and two negative versions, each ending in a word related to one of the two different bias sentences. The resulting 480 target sentences were distributed over four lists in a counterbalanced fashion. Thus, half of the subjects were shown the first bias list combined with on of the four target lists, and the other subjects saw the second bias list with one of the target lists. The combination with the bias sentence determined the truth (or consistency) of the target sentence and, obviously, the relationship between target ending and bias sentence. So, endings that were true and related to the bias for one group of subjects were false and unrelated for the other group. Table

3-1 demonstrates how combinations of bias and target versions result in the four different sentence types.

3.1.1.3 Procedure

Having given informed consent to participate in the study, subjects completed the Edinburgh handedness inventory (Oldfield, 1971) as well as the Author and Magazine Recognition Questionnaires (Stanovich & Cunningham, 1992). Next, the Stroop test was administered: Subjects were first instructed to name the color of each string of letters on the first sheet as fast as possible, and the time to complete the sheet was recorded. They completed the interference condition in the same manner, after they were told to not read the color words but to name the color of the ink.

After the application of the electrodes to the head, subjects completed the experiment in a sound-proof, electrically shielded chamber. They were seated in a comfortable chair approximately 75 cm in front of a computer screen. Subjects were told that they would be reading short stories describing choices different people made. Their task was to decide whether the final sentence of the story was consistent with the information previously received. No timing instructions were given for the verification task or the self-paced reading of the introduction and bias sentences. Subjects were given a sample story and examples of consistent (true) and inconsistent (false) endings. The session began with a practice run of four scenarios, including one of each of the four target sentence types.

Each new trial was initiated by the subject's button press. After a 1000 ms blank screen, the two introductory sentences appeared together on the screen, where they remained until the next button press. Then the bias sentence was presented as a whole until the subject pressed a button. It was followed by a row of three crosses ("+++") to orient the subject's attention to the center of the screen. Following a 200 ms blank screen, the final sentence was presented word by word with a Stimulus Onset Asynchrony (SOA) of 500 ms and a word duration of 200 ms. Following the final word, the screen remained blank until 1000 ms after the subject had pressed a response button. The sentence "Please press a button to read the next story." was then shown until the subject initiated the next trial.

The trials were grouped into six blocks. After each block, subjects were encouraged to take a break. Usually, subjects completed a block in less than ten minutes, and the experiment rarely lasted more than an hour.

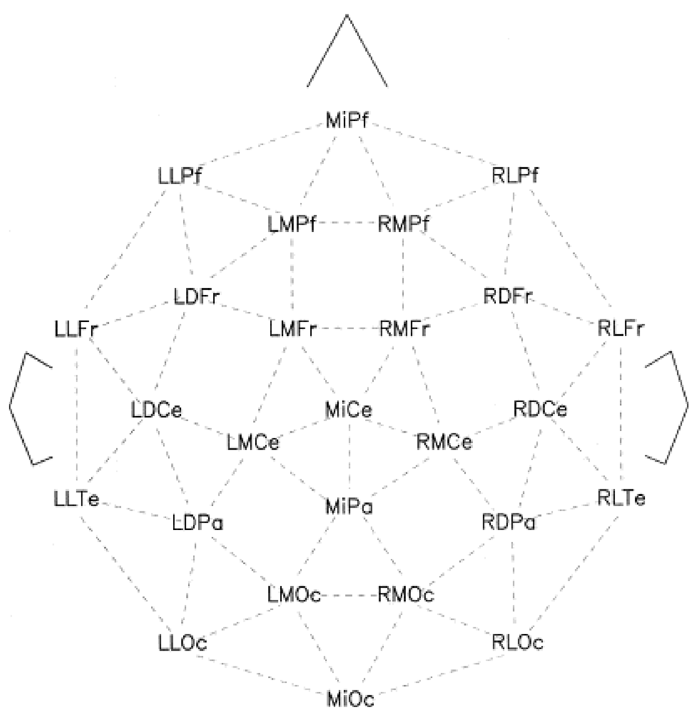


Figure 3-1. Schematic of the electrode array used in the ERP experiments.

3.1.1.4 EEG Recording

The EEG was recorded from 26 tin electrodes geodesically arranged in an electrode-cap (see Figure 3-1). The left mastoid served as reference. To control for blinks and horizontal eye movements, additional electrodes were on the outer canthi of the eyes (referenced to the left canthus) and on the right infraorbital ridge (referenced to the left mastoid). All impedances were kept below 5 kΩ. The EEG was bandpass filtered (0.01 – 100 Hz) and continuously digitized at a rate of 250 Hz.

3.1.1.5 Data Analysis

Accuracy

Data about response accuracy were submitted to a mixed-effects logistic regression with three main effects, trial number, truth, negation (including the interaction between truth and negation), as well as two random factors, Subject and Item. Trial number was included to reduce error variance, while truth and negation were the main factors of interest. In case of a significant truth x negation interaction, pairwise comparisons were carried out by running separate regression models with trial and Sentence Type as fixed effects. The p-values derived from these post-hoc models were adjusted for multiple comparisons using Hochberg's improved Bonferroni procedure (Hochberg, 1988).

Response Times

To improve the normality of their distribution, response times were logarithmically transformed (base 10). All statistics were performed on these log-transformed values. For easier comprehension, descriptive statistics were back-transformed (via exponentiation) for presentation in figures.

Trials with incorrect responses were excluded from all analyses. Furthermore, outliers were eliminated: Means and standard deviations were computed for each subject and sentence type, and data points whose distance from their corresponding mean was more than a certain number of standard deviations were rejected, with the cutoff depending on the number of valid trials for a given subject and condition (Van Selst & Jolicoeur, 1994). Approximately 4% of trials were excluded from the analyses.

The resulting data were analyzed with a mixed-effects model including trial, truth, negation, and the truth by negation interaction as fixed effects, as well as Subject and Item as random effects. A significant truth x negation interaction was resolved by performing pairwise comparisons. These comparisons were carried out as simultaneous hypothesis tests based on the normal approximation to the multivariate t-distribution (cf. Bretz, Hothorn, & Westfall, 2002; Westfall, Tobias, Rom, Wolfinger, & Hochberg, 1999). To correct for multiple comparisons, p-values were adjusted following Hochberg's (1988) method.

ERPs

EEG data were re-referenced off-line to the algebraic mean of the two mastoids. Trials contaminated by eye-movements, excessive muscle activity, or amplifier blocking were excluded. For ERPs to sentence-final targets, trials on which subjects made an incorrect verification decisions were also excluded. Overall, 8% of trials were lost for target words, and 2% for verbs.

ERPs to the verb and the final word of the target sentence were computed by averaging epochs ranging from 100 ms before until 920 ms post word onset, after subtraction of a 100 ms pre-stimulus baseline. For ERPs to verbs, mean amplitudes were computed for a time-window ranging from 100 to 920 ms. For sentence-final target words, the time-windows were 150–200 ms (P2), 200–400 ms (N400), 400–600 ms (LPC), and 600–900 ms.

Mean amplitude values were submitted to repeated measures ANOVAs with truth, negation, and electrode as within-subjects factors. All reported p-values for effects with more than one degree of freedom (which was the case in interactions with the factor electrode) were adjusted using the Greenhouse-Geisser correction (Greenhouse & Geisser, 1959). The original degrees of freedom for the F-statistic are reported along with the adjustment factor ε. In the case of a significant interaction between electrode and another factor, four contrasts were computed to assess the shape of the distribution: We tested whether the effect differed between left and right, medial and lateral, frontal and posterior, as well as central and non-central electrode sites. More information about these contrasts, including the weights for the individual electrodes, is presented in Appendix C.

For pairwise comparisons of the four sentence types, data for each condition were averaged over all electrodes and submitted to t-tests. The derived p-values were adjusted for multiple comparisons (cf. Hochberg, 1988). In general, pairwise comparisons were carried out when a significant truth by negation interaction was found. They were always done for the N400 (200–400 ms), the dependent measure of primary interest.

3.1.2 Results for the Entire Sample

Subjects scored an average of .176 (*SD* = .065) on the ART and 0.300 (*SD* = .124) on the MRT. These values are notably lower than those reported for larger samples of students by Stanovich and Cunningham (1993, *n* = 268) and Stanovich et al. (1995, *n* = 133), who reported mean ART scores of .238 (*SD* = .145) and .327 (*SD* = .14), respectively, and average MRT scores of .486 (*SD* = .162) and .512 (*SD* = .15), respectively. This might indicate that the fourth versions of these culturally sensitive tests were somewhat outdated and therefore not appropriate for the college population that was tested in this experiment. Mean completion times for the Stroop were 36.2 seconds (*SD* = 5.9 s) on the neutral and 56.4 seconds (*SD* = 10.7 s) on the interference version, corresponding to an average interference cost of 56%.

3.1.2.1 Verification

Accuracy

Accuracy was high with a rate of 96% correct responses overall, and error rates decreased over the course of the experiment (Wald z = 3.02, p = .003). There was not much variability among the sentence types, which is apparent in Figure 3-2. Neither truth (Wald z = -0.50, p = .519) nor negation (Wald z = 1.59, p = .112) had a significant effect on error rate. There was a marginally significant truth x negation interaction (Wald z = –1.89, p = .059). Post-hoc tests did not reveal any significant differences, although the comparison of TA and TN was significant before adjustment for multiple comparisons (*cf*. Table 3-2).

Table 3-2. Pairwise comparisons for Accuracy in Experiment 1a. Wald z statistics and raw p values are shown. The right-most column indicates whether the comparison is significant at the .05 level after Hochberg (1988) adjustment, with the asterisk (*) indicating significance.

	Wald z	p	Significance
TA – FA	0.33	.740	n.s.
TA – FN	1.30	.192	n.s.
TA – TN	2.41	.016	n.s.
FA – FN	0.40	.691	n.s.
FA – TN	1.09	.276	n.s.
FN – TN	1.02	.309	n.s.

<u>Response Times</u>

Figure 3-2 shows RTs in milliseconds by sentence type, and Table 3-4 presents descriptive statistics for the log-transformed RTs, on which the inferential analyses are based. Subjects verified affirmative sentences faster than negative ones [$F(1, 3688) = 158.93$, $p < .001$], and true sentences faster than false ones [$F(1, 3688) = 64.06$, $p < .001$]. The significant truth x negation interaction [$F(1, 3688) = 22.47$, $p < .001$] indicated that the RT difference due to truth was larger for affirmative than negative sentences, but both were significant, as were all pairwise comparisons (cf. Table 3-3). Also, RTs on later trials were faster than those on earlier ones [$F(1, 3688) = 256.46$, $p < 0.001$].

Table 3-3. Multiple comparisons of RTs in Experiment 1a. Raw *p* values are reported, and the last column indicates with an asterisk (*) which effects are significant at the .05 levels using Hochberg's (1988) adjustment method.

	z	*p*	Significance
TA – FA	–9.02	<.001	*
TA – FN	–14.55	<.001	*
TA – TN	–12.24	<.001	*
FA – FN	–5.53	<.001	*
FA – TN	–3.25	.001	*
FN – TN	2.27	.023	*

Table 3-4. Response times for Experiment 1a. The first row shows averages and standard deviations (in parantheses) based on all individual data points, which were the used in the mixed-model analysis. For comparison purposes, the second row presents the same statistics for traditional by-subject averages, the basis for Figure 3-2.

	TA	FA	TN	FN
Prior Averaging				
None	2.968 (0.186)	3.031 (0.175)	3.052 (0.189)	3.068 (0.182)
By-Subject	2.968 (0.102)	3.030 (0.106)	3.053 (0.094)	3.068 (0.099)

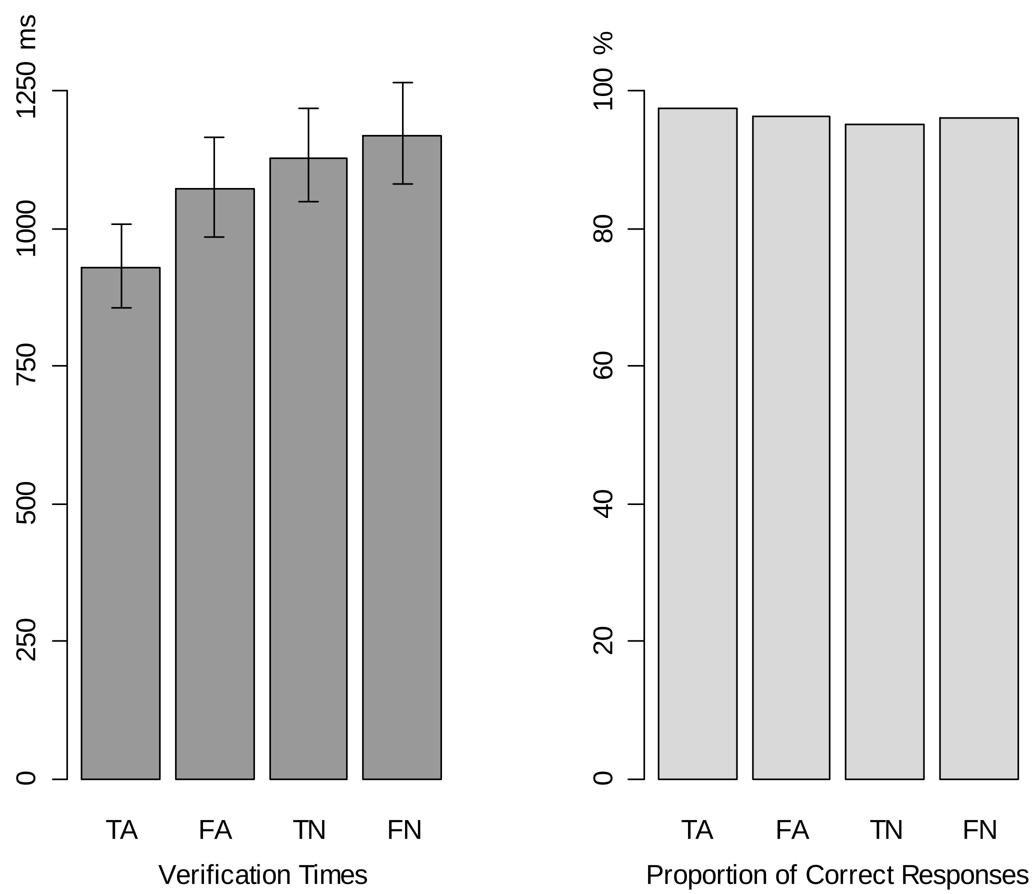


Figure 3-2. Verification results for Experiment 1a. The left panel shows mean response times with 95% confidence intervals. Means and standard errors were computed on by-subject averages of log-transformed data. Back-transformed values are shown. The right panel shows the proportion of correct responses computed over all subjects and items.

3.1.2.2 Event-Related Potentials

Verbs

Figure 3-3 shows ERPs to the verbs in the final sentences of the stories. The plots indicate that verbs in negative sentences elicit more negative ERPs than verbs in affirmative sentences. Measured in a time-window from 100 to 900 ms, this effect was highly significant [$F(1, 31) = 58.99$, $p < .001$]. Its size differed across electrode sites [$F(25, 775; \varepsilon = .137) = 13.17$, $p < .001$]: the difference was larger on the left than on the right side of the head [$t(31) = -2.42$, $p = .021$], at medial compared to lateral locations [$t(31) = -3.81$, $p < .001$], as well as at central [$t(31) = -2.93$, $p = .006$] and frontal [$t(31) = 3.77$, $p < .001$] compared to non-central and posterior channels, respectively. This negation effect was not affected by the truth of the sentences [truth x negation: $F(1, 31) < 1$; truth x negation x electrode: $F(25, 775; \varepsilon = .188) = 1.99$, $p = .087$], and truth did not have an independent effect, either [main effect and interaction with electrode: both *F*s < 1]. This is expected, as the target word, which rendered the sentence true or false, occurred only after the end of the epoch for almost all sentences; in only seven out of 120 sentences did the target word immediately follow the verb and therefore affect the later part of the ERP.

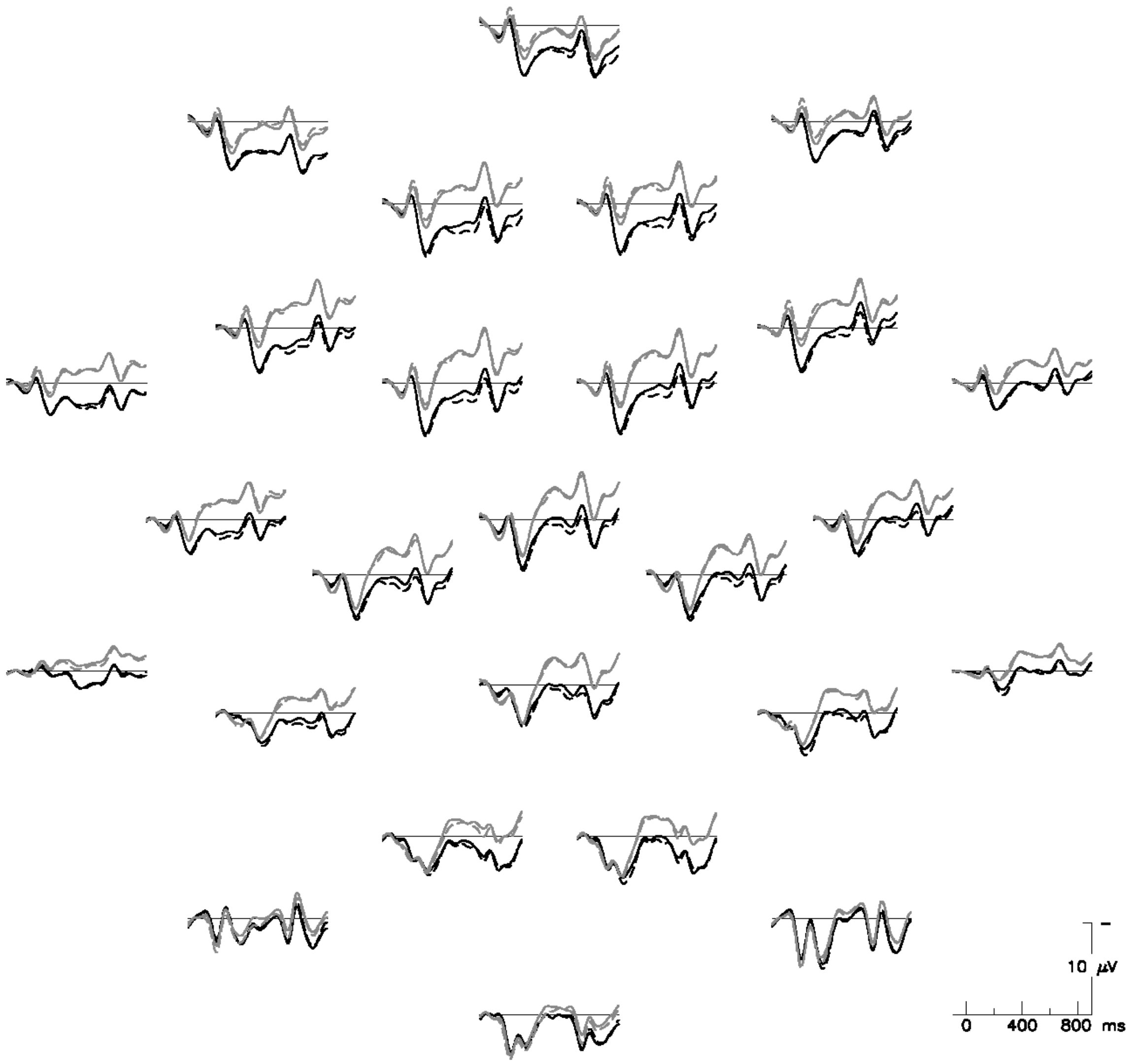
Sentence-Final Targets

The grand average ERPs to sentence-final target words are presented in Figure 3-4. Following early sensory components that were similar for all conditions, the ERPs diverged as a function of sentence type. At fronto-central sites, a uniform negativity peaking around 100 ms (N1) preceded a positivity with a peak around 220 ms (P2) that was larger in negative sentences than in affirmative ones. A posterior positivity and negativity peaking at approximately 100 and

170 ms, respectively (P1-N1 complex), were followed by a positive peak around 290 ms that showed some differentiation among ending types, possibly because of overlap with the following negativity. FA and to a lesser extent FN were associated with a negative going waveform (N400) that peaked around 300 ms at frontal and at approximately 360 ms at more posterior electrode sites. At posterior channels, false endings subsequently showed a positivity (late posterior component; LPC) between about 400 and 600 ms. After 600 ms, targets in affirmative sentence contexts elicited more negative ERPs at central electrodes than targets in negative sentences.

<u>150 – 200 ms</u>

As is visible in Figure 3-5, ERPs to the targets showed effects of both truth and negation as early as 150 ms after word onset. Words in negative sentences elicited a larger positivity (P2) than those in affirmative ones [$F(1, 31) = 8.61$, $p = .006$]. The size of this effect varied as a function of electrode site [$F(25, 775;\ \varepsilon = .163) = 3.36$, $p < .001$], with a more pronounced positivity over central [$t(31) = 2.64$, $p = .013$] and medial [$t(31 = 3.03$, $p = .005$] scalp locations. Visually, it also appeared to be larger on the left, but the effect failed to reach significance [$t(31) = 1.67$, $p = .106$]. Truth did not have a significant main effect ($F(1, 31) < 1$], but its effect differed among electrode sites [$F(25, 775;\ \varepsilon = .154) = 1.86$, $p = .007$]: At right scalp locations only, false endings were associated with a larger negativity than true endings [$t(31) = –2\ .376$, $p = .024$], indicating that the onset of the N400 occurred already before 200 ms at these electrode sites. There were no interactions involving truth and negation [truth x negation and truth x negation x electrode: both Fs < 1].

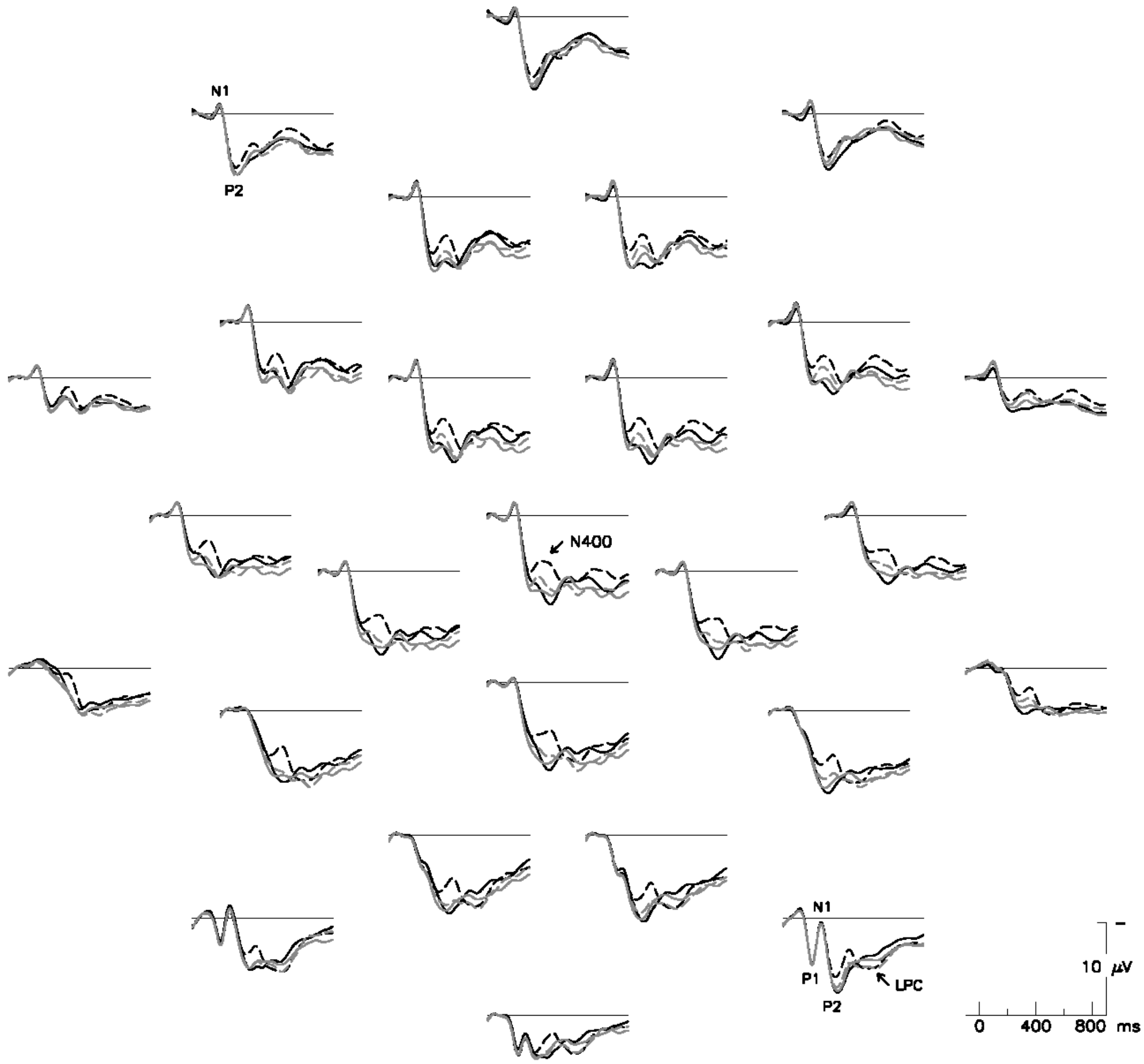


Joe wanted something salty. So he...

——— ***BOUGHT** the pretzels.* (TA) ——— *didn't **BUY** the cookies.* (TN)

----- ***BOUGHT** the cookies.* (FA) ----- *didn't **BUY** the pretzels.* (FN)

Figure 3-3. ERPs to final-sentence verbs in Experiment 1a.



Joe wanted something salty. So he...

——— ***bought the PRETZELS.*** (TA) ——— ***didn't buy the COOKIES.*** (TN)

- - - - - ***bought the COOKIES.*** (FA) - - - - - ***didn't buy the PRETZELS.*** (FN)

Figure 3-4. Grand average ERPs to sentence-final target words in Experiment 1a. The electrode layout corresponds approximately to the schematic in Figure 3-1. Major ERP components are labeled.

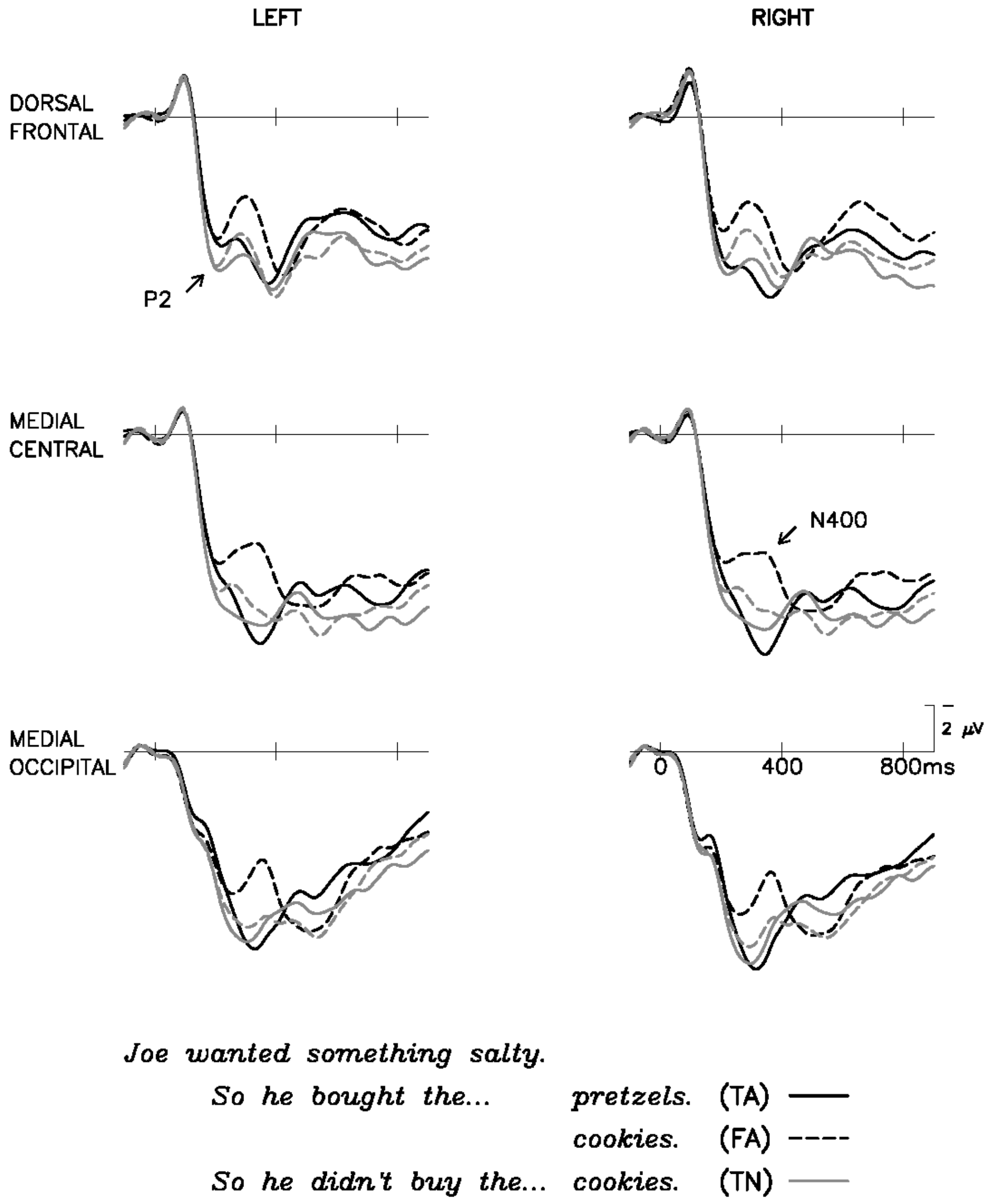


Figure 3-5. ERPs to target words in Experiment 1a at six selected electrode sites (LDFr, RDFr, LMCe, RMCe, LMOc, RMOc). The P2 and N400 components are labeled.

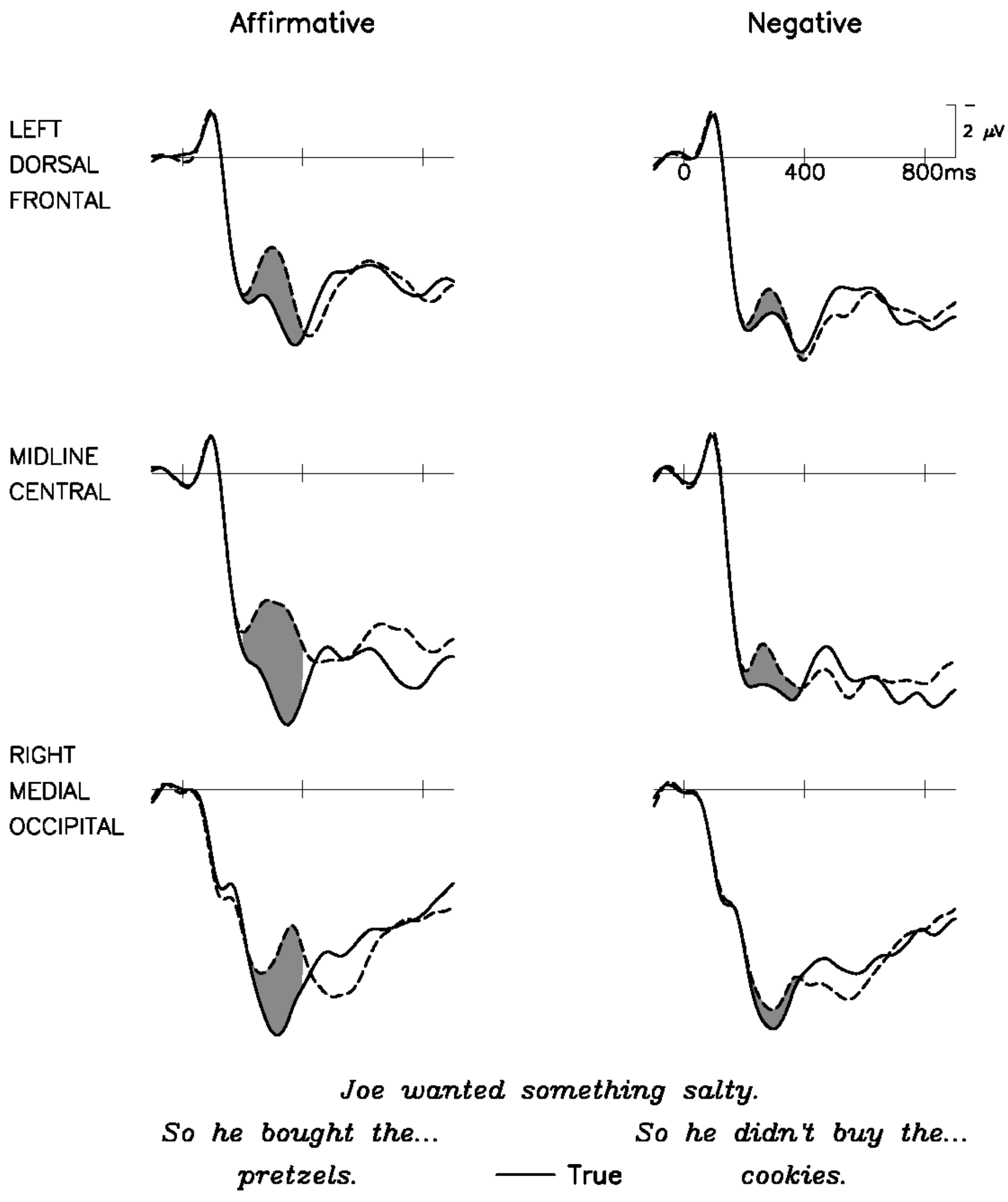


Figure 3-6. ERPs to true and false endings presented separately for affirmative and negative sentences (Experiment 1a). The same three electrode sites are shown for the two sentence modes. The difference between true and false endings is shaded in N400 time-window (200-400 ms).

200 – 400 ms

Based on visual inspection of the grand average ERPs, it was decided to measure the N400 effect between 200 and 400 ms. This is a relatively early time-window for the N400 given that its peak usually occurs around 400 ms, the end of the time-window used in this study. Indeed the N400 in this data set peaked much earlier than in sentence reading studies, however, this is not unusual for a verification experiment. Fischler and colleagues found peak latencies of 320, 340, and 380 ms for N400s in verification studies (Fischler, Bloom, Childers, Arroyo, & Perry, 1984; Fischler et al., 1983; Fischler, Childers, Achariyapaopan, & Perry, 1985).

Statistical analyses revealed main effects of truth [$F(1, 31) = 33.50$, $p < .001$] and negation [$F(1, 31) = 11.09$, $p = .002$], and the two-way interactions with electrode were also significant for both factors [truth: $F(25, 775$; $\varepsilon = .187) = 7.36$, $p < .001$; negation: $F(25, 775$; $\varepsilon =.161) = 4.33$, $p = .002$]. Sentence-final words in negative sentences elicited more positive ERPs than affirmative sentence endings. This was probably due to overlap with the P2 increase for negative sentence targets, which carried over into the N400 time-window. Like the P2 effect, the positivity in the 200-400 ms time-window was larger at central [$t(31) = 3.22$, $p = .003$] and medial [$t(31) = 2.31$, $p = .028$] scalp locations. It was also greater at on the left than on the right [$t(31) = 3.19$, $p = .003$], which resembles the pattern found for the P2, although it did not reach significance there. The main effect of truth reflected the larger negativity associated with false endings compared to true ones. It was more pronounced at medial [$t(31) = 3.99$, $p < .001$] and central [$t(31) = 3.88$, $p < .001$] scalp locations, and it was larger on the right than on the left [$t(31) = -2.65$, $p = .013$].

The size of the truth effect differed between affirmative and negative sentences, which was reflected by the significant truth x negation interaction [$F(1,31) = 6.77$, $p = .014$] that was observed across the scalp [truth x negation x electrode: $F(25, 775;\ \varepsilon = .122) = 1.27$, $p = .289$]. Firgure 3-6 illustrates that the truth effect was larger in affirmative sentences than in negative ones. Indeed, pairwise comparisons revealed that it was significant only for affirmative sentences: FA elicited significantly larger N400s than TA, but N400s to FN and TN did not differ reliably. Table 3-5 shows that FA were different from all other sentence types, which in turn did not differ significantly from each other. Note, however, that comparisons of the N400 to affirmative and negative sentence endings (e.g., TA vs. TN) are problematic and hard to interpret because of the spillover of the P2 difference between affirmative and negative endings into the N400 time window.

Table 3-5. Pairwise comparisons of sentence types for N400 amplitude in Experiment 1a. Raw *p* values are shown, and differences that are significant after Hochberg (1988) adjustment at the .05 level are marked with an asterisk (*) in the last column.

	$F(1, 31)$	p	Significance
TA – FA	26.57	<.001	*
TA – FN	3.59	.067	n.s.
TA – TN	0.08	.785	n.s.
FA – FN	19.14	<.001	*
FA – TN	64.35	<.001	*
FN – TN	2.73	.108	n.s.

400 – 600 ms

In the time-window following the N400, ERPs to false sentence endings were more positive than those to true endings. This significant truth effect [$F(1, 31) = 4.41$, $p = .044$] varied in size across the scalp [$F(25, 775; \varepsilon = .215) = 2.22$, $p = 0.050$]: it was larger over the back than over the front of the head [$t(31) = -2.13$, $p = .041$], as is clearly visible in Figures 3-5 and 3-6. Negation didn't have a reliable effect on mean voltage in this time-window [$F(1, 31) = 2.46$, $p = .127$; negation x electrode: $F(25, 775; \varepsilon = .129) = 1.28$, $p = .284$], and the size of the truth effect did not differ between affirmative and negative sentences [truth x negation and truth x negation x electrode: both *F*s < 1]. Overall, its sensitivity to truth, a task-relevant factor, as well as its posterior distribution suggest that the positivity was an instance of the late posterior complex (LPC).

600 – 900 ms

Beginning at approximately 600 ms, the ERPs showed a prolonged divergence between affirmative and negative sentences [$F(1, 31) = 15.39$, $p < .001$] that varied in size across the scalp [$F(25, 775; \varepsilon = .198) = 3.25$, $p = .008$]. Endings in affirmative sentences were more negative than those in negative sentences, and the difference was most pronounced at central [$t(31) = 3.28$, $p = .003$] and medial [$t(31) = 2.31$, $p = .028$] scalp locations. This effect was not affected by the truth of the sentence [truth x negation: $F(1, 31) = 1.80$, $p = .190$; truth x negation x electrode: $F(25, 775; \varepsilon = .183) = 1.52$, $p = .193$], and truth itself did not have an independent effect, either [main effect and interaction with electrode: both *F*s < 1].

3.1.2.3 Summary of Main Results

Subjects verified affirmative sentences faster than negative ones, and true sentences faster than false ones. The RT difference due to truth was larger in affirmative compared to negative sentences. The N400 showed a similar interaction between truth and negation: False sentence endings elicited larger negativities than true ones, but the effect reached significance only for affirmative sentences. Importantly, N400 amplitude was not simply determined by the lexical level relation between bias sentence and target word (as was the case in the Fischler et al., 1983 study), as the truth effect was clearly *not* reversed between affirmative and negative sentences: FN endings, which were related to the bias sentence, elicited N400s that were larger than or similar to the N400 to TN targets, which were not directly related to the content of the bias sentence. Thus, truth had at least as much of an effect on target N400 amplitude as the semantic relation between the target and previously mentioned words. Negation, which changes the truth of a sentence, must therefore have played some role in the processing of the final word of the target sentence.

Truth also affected the LPC, resulting in a larger positivity to false than to true endings. Additional effects distinguished affirmative and negative sentences. They were found on the target as well as on words preceding it. ERPs to negative targets started to show a positivity (P2 effect) around 150 ms after word onset, and beginning around 600 ms after stimulus onset, they were again less negative (i.e. more positive) than those to affirmative targets. Preceding the target, sentence segments following a negation marker were associated with more negative going ERPs than the same words in affirmative contexts.

3.1.3 Subject Groups

The average results presented for the entire subject sample hide an important fact: There was great inter-individual variability, most notably in the N400 data. In some subjects, the N400 truth effect was the same for affirmative and negative sentences, while it was completely reversed in others. In order to explore possible reasons for these diverging data patterns, subjects were sorted into two groups and then compared on a number of measures. One group (‘FN > TN’, $n = 19$) contained all subjects in whom the N400 to FN was larger than the N400 to TN at the midline central electrode (MiCe). The second grouped contained the remaining subjects (‘FN ≤ TN’, $n = 13$), in whom the N400 to FN were smaller than or similar to the TN N400.

In a first step, these two groups were compared with respect to all ERP and RT measures that were previously analyzed for the whole sample. Since the N400 data were the basis for the categorization, the groups should certainly differ in their N400 patterns. Given the similarity of RT and N400 data for the whole sample, the groups could also be expected to show divergent RT patterns: Subject with larger N400s to FN should also have longer RTs to FN (compared to TN), and subjects with smaller N400s to FN should also have taken lass time to verify FN. No particular hypotheses were formulated for the analyses of the remaining mean amplitude measures as well as accuracy; these were done mainly for exploratory purposes.

In a second step, hypotheses about potential reasons for the diverging N400 patterns were tested. One hypothesis was that the groups differed in language or cognitive abilities. Subjects with higher linguistic ability or better cognitive control might be faster at integrating negation into the sentence context and updating their expectations about the continuation of the sentence. So they should show an advantage (smaller N400) for TN over FN. The groups were therefore compared on their ART, MRT, and Stroop scores.

Another possible explanation is that subjects differed in the way they processed information prior to the target sentence, namely the bias sentence. The inferences derived from the bias sentence are the basis for the expectations about the final sentence. A subject might, for instance, learn that *Joe wanted something salty*. Knowing that he had a choice between pretzels and cookies, she could directly infer that Joe would buy pretzels. Yet, another, less direct conclusion is warranted by the information, namely that Joe would not buy cookies. Experimental evidence suggests that subjects usually draw this kind of logical inference when reading narratives. The result of the inference, however, does not necessarily become or remain activated (Lea & Mulligan, 2002), probably because it is negated and therefore backgrounded. In the context of this experiment, keeping this negative inference active in working memory would be beneficial as it facilitates the verification of negative sentences, and some subjects may therefore have made an effort to do this. Others may not have employed this strategy, and as a result the negative inference would not be (as) available to them during the processing of the subsequent target sentence. These subjects would then not be able to predict the 'true' ending for a negative target sentence, which should lead to a disadvantage (larger N400) for TN compared to FN, whose ending is related to the bias sentence and corresponds to the automatic affirmative inference. Differences in processing the bias sentence may manifest themselves in the time subjects took to process the sentence as well as in the ERP. The 'FN > TN' group might show longer reading times for the bias sentence than the 'FN ≤ TN' group, reflecting the extra time for activating the negative inference. No specific prediction is proposed for the ERPs to the bias sentence; the goal was simply to detect any (*a priori* undefined) difference that might help explain the group differences in N400 patterns.

3.1.3.1 Data Analysis

<u>Verification and ERPs to Verbs and Sentence-Final Targets</u>

For response times, accuracy, and mean amplitude data, the analyses conducted on the whole sample were repeated with the additional factor group. When a significant interaction involving group was found, separate analyses were carried out for the two subject groups.

<u>Cognitive Tests</u>

Using the Wilcoxon rank-sum test, the groups were compared with respect to their ART, and MRT scores, their times on the neutral and interference Stroop, as well as the relative interference cost on the Stroop test [computed as (interference – neutral)/neutral].

<u>Reading Times for Bias Sentence</u>

Bias sentence reading times were analyzed through a mixed-effects analysis including group, as well as the potentially confounding factors trial and length (in number of words) as fixed effects and Subject and Item as random effects.

<u>Event-Related Potentials to Bias Sentence</u>

In addition to the verb and target word averages, ERPs to the bias sentence were computed for epochs from 200 ms before until 1840 ms after sentence onset, with a 200 ms pre-stimulus baseline. As subjects had been reading entire sentences on the screen (which necessarily involves saccadic eye movements) and had not been instructed to suppress blinks while reading these sentences, artifact rejection would have eliminated every single trial. These

ERPs were therefore based on all trials, irrespective of the artifacts that they possibly (and likely) contained. Mean amplitudes were computed for a time-window from sentence-onset to 700 ms after sentence onset. The resulting values were submitted to an ANOVA with group as between-subject and electrode as repeated-measures factor.

3.1.3.2 Event-Related Potentials to Target-Sentence Words

<u>N400 (200 – 400 ms)</u>

Figure 3-9 shows the ERPs to sentence-final targets for the two subject groups side by side. The groups differed in the ordering of the N400s to FN and TN, which is expected, since the N400 to negative sentence endings was the categorization criterion. The negation effect was similar for both groups across the scalp [group x negation and group x negation x electrode: both *F*s < 1]. group interacted, however, with truth [$F(1, 30) = 13.18$, $p = .001$] as well as with truth and negation [$F(1, 30) = 6.21$, $p = .018$].

ERPs for the 'FN > TN' group are presented in Figure 3-7. The truth effect was significant [$F(1, 18) = 62.52$, $p < .001$], while truth x negation interaction was not [$F(1,18) < 1$]. That is, the truth effect did not differ between affirmative and negative sentences. Both types of false sentence endings elicited larger N400s than both true ending types, but the difference between TA and TN and that between FA and FN did not reach significance (*cf*. Table 3-6).

Figure 3-8 shows that in the 'FN ≤ TN' group, the truth effect was reversed between affirmative and negative sentences. FA elicited significantly larger negativities than TA, but numerically smaller N400s were observed for FN than for TN, although this difference failed to reach significance after adjustment for multiple comparisons (*cf*. Table 3-7). Correspondingly, the truth x negation interaction was significant [$F(1, 12) = 11.65$, $p = .005$], while the main effect of truth was not [$F(1, 12) = 2.16$, $p = .167$].

The distribution of the truth effects also differed between groups [$F(25, 750; \varepsilon = .207) = 3.86$, $p = .002$], but the distribution of the truth x negation interaction did not [$F(25, 750; \varepsilon = .124) = 1.88$, $p = .137$]. In the 'FN > TN' group, where the truth main effect was significant, its size also varied across the scalp [$F(25, 450; \varepsilon=.205) = 10.44$, $p < .001$]. It was larger at right [$t(18) = -3.04$, $p = .007$], medial [$t(18) = 4.59$, $p < .001$], and central [$t(18) = 4.31$, $p < .001$] electrodes. The truth effect in the 'FN ≤ TN' group, which was not significant overall, also did not interact with electrode site [$F(25, 300; \varepsilon = .145) = 1.20$, $p = .323$]. Basically, the truth effect varied in size across the scalp only when it was actually present.

The truth effect within affirmatives, which was significant in both groups also showed similar distributions [$F(25, 750; \varepsilon = .188) < 1$]. Likewise, the distribution of the reversed truth effect for negatives in the 'FN ≤ TN' group did not differ significantly from the "regular" truth effect in the 'FN > TN' group [$F(25, 750; \varepsilon = .268) = 1.12$, $p = .351$]. So the truth effect distributions were actually similar between the groups. It was only the averaging of a normal with a reversed truth effect in the 'FN ≤ TN' group that eliminated both the truth main effect and its interaction with electrode site.

Table 3-6. Pairwise comparisons of sentence types on N400 amplitude for the 'FN>TN' subject group. Raw p values are shown, and differences that are significant after Hochberg (1988) adjustment at the .05 level are marked with an asterisk (*) in the last column.

	F(1, 18)	*p*	Significance
TA-FA	16.63	<.001	*
TA-FN	7.34	.014	*
TA-TN	0.74	.400	n.s.
FA-FN	5.86	.026	n.s.
FA-TN	79.76	<.001	*
FN-TN	42.66	<.001	*

Table 3-7. Pairwise comparisons of sentence types on N400 amplitude for the subject 'FN ≤ TN' group. Raw *p* values are shown, and differences that are significant after Hochberg (1988) adjustment at the .05 level are marked with an asterisk (*) in the last column.

	F(1, 12)	*p*	Significance
TA-FA	9.27	.010	*
TA-FN	0.19	.672	n.s.
TA-TN	3.54	.084	n.s.
FA-FN	16.78	.001	*
FA-TN	11.91	.005	*
FN-TN	6.82	.023	n.s.

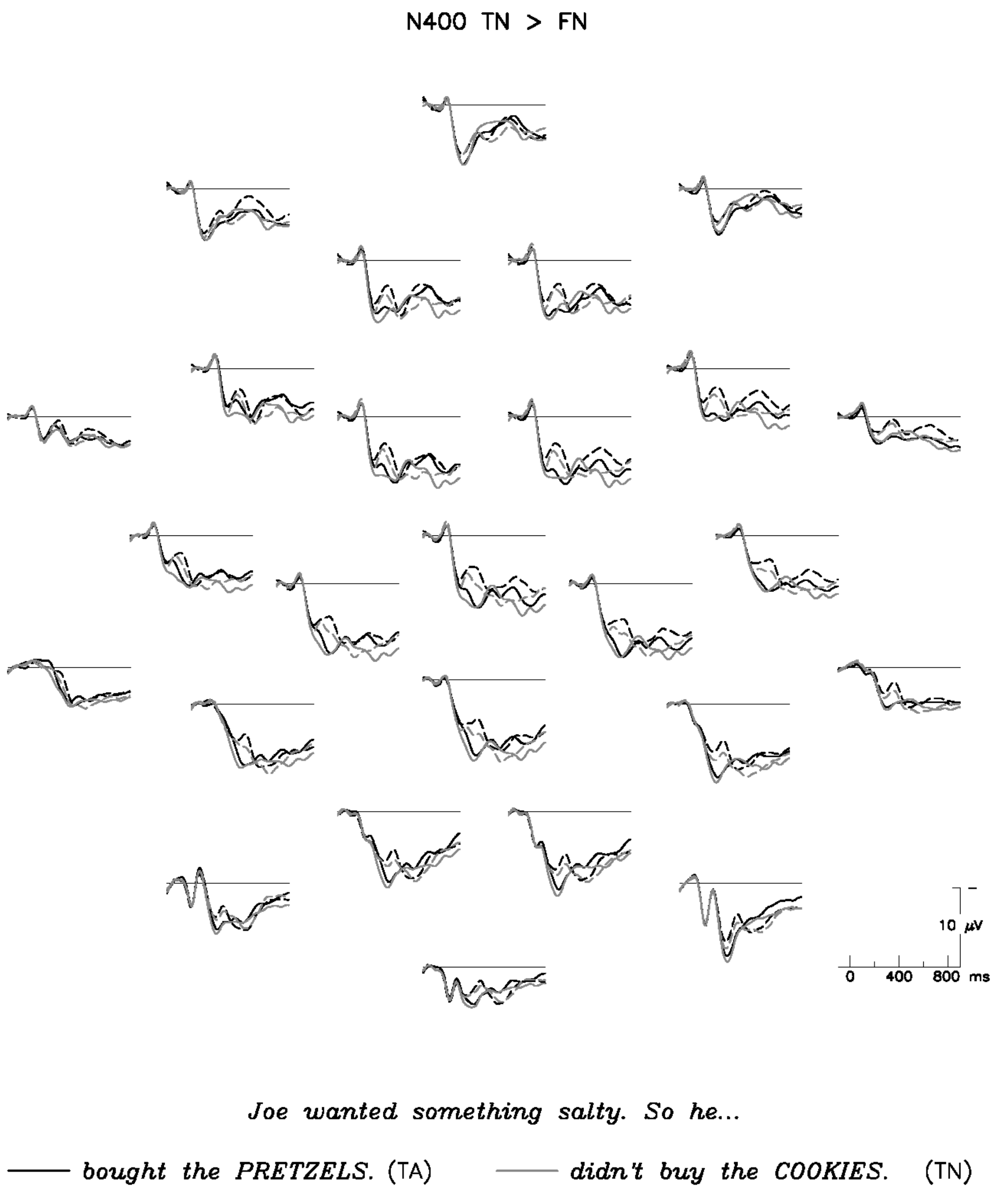


Figure 3-7. ERPs to target words for the 19 subjects in Experiment 1a who showed a larger N400 to FN than TN.

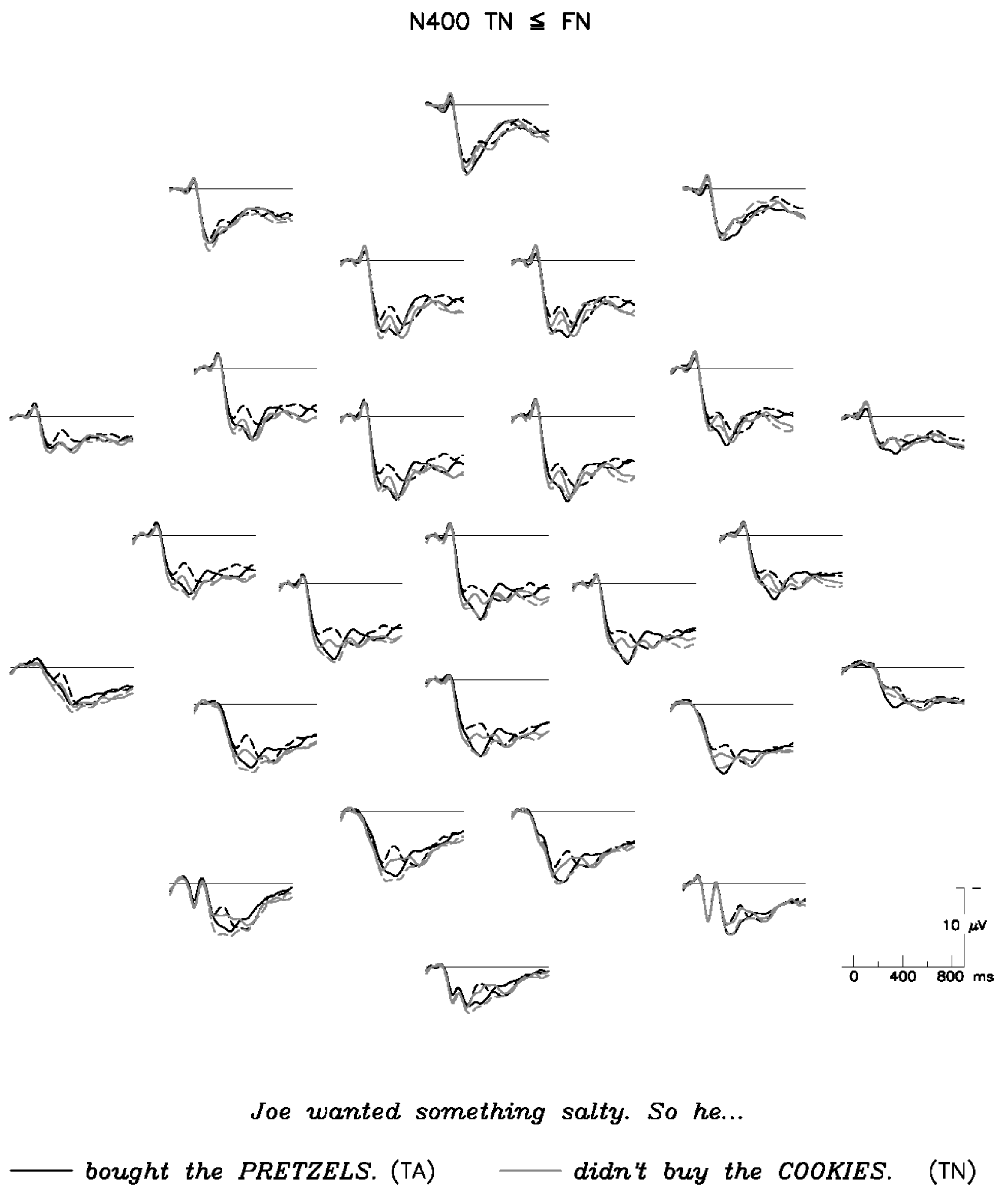


Figure 3-8. ERPs to target words for the 13 subjects in Experiment 1a who showed a smaller or equally large N400 to FN compared to TN.

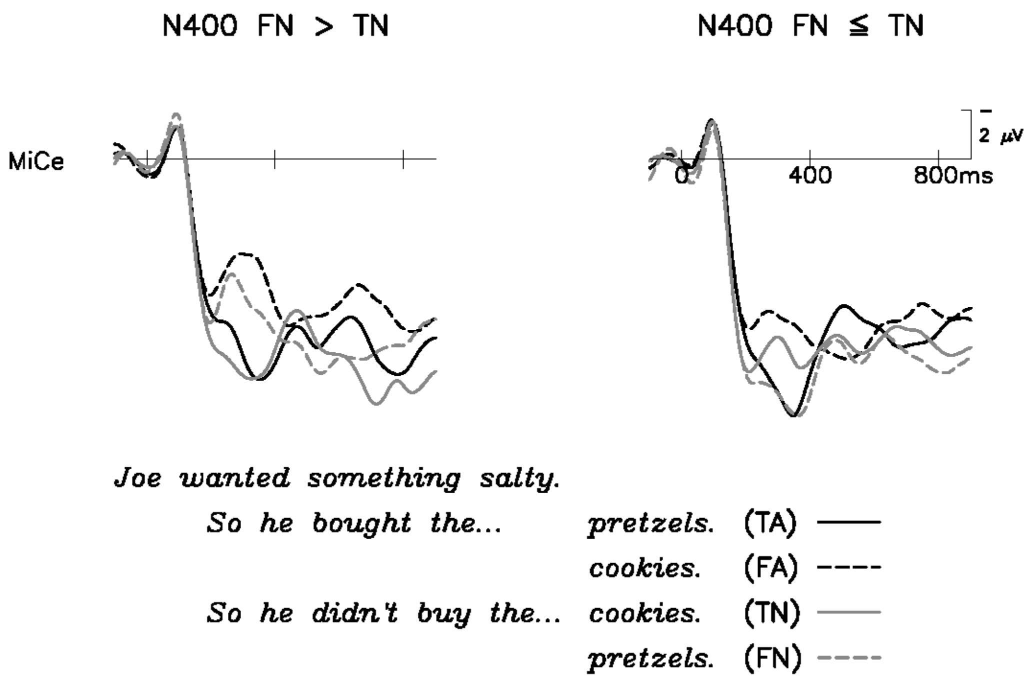


Figure 3-9. ERPs to sentence-final targets for the two subject groups in Experiment 1a. The midline central channel (MiCe) is plotted for both groups.

Other ERP Effects

No interactions involving group were found for the verb and for the sentence-final words in the 150-200 and the 600-900 ms time-windows [all *p*s > .1]. For the LPC (400-600 ms), only the four-way interaction between group, truth, negation, and electrode was significant [$F(25, 750; \varepsilon = .149) = 3.21$, $p = .018$; all other *p*s > .1], but no significant effects were found in either group. In the 'TN > FN' group, a non-significant trend toward a smaller truth effect at more frontal channels for affirmative sentences only was observed [truth x negation x electrode: $F(25, 450; \varepsilon = .144) = 2.22$, $p = .083$; anteriority contrast: $t(18) = -1.90$, $p = .073$]. For the 'TN <

FN' group, there was a non-significant trend toward a truth x electrode interaction [$F(25, 300; \varepsilon = .170) = 2.08$, $p = .094$], due to a marginally reduced truth effect at lateral [$t(12) = -1.85$, $p = .089$] and frontal [$t(12) = -2.15$, $p = .053$] channels.

3.1.3.3 Verification

Error rates were independent of group membership [all *p*s > .1]. Response time patterns, by contrast, varied between groups. As for the N400, group interacted with truth [$F(1, 3684) = 6.361$, $p = .012$] as well as with truth x negation [$F(1, 3684) = 4.91$, $p = .027$], while the negation effect was independent of group [$F(1, 3684) < 1$]. The main effect of truth [FN > TN: $F(1, 2183) = 61.19$, $p < .001$; FN ≤ TN: $F(1, 1500) = 8.80$, $p = .003$] and the truth x negation interaction [FN > TN: $F(1, 2183) = 4.962$, $p < .026$; FN ≤ TN: $F(1, 1500) = 20.88$, $p < .001$] were significant for both groups. However, the relationship between TN and FN differed between the groups, as Figure 3-10 shows. For the 'FN > TN' group, the interaction was ordinal: The truth effect in negative sentences was smaller than in affirmative sentences, but it pointed in the same direction. That is, in both affirmatives and negatives, false sentences were verified more slowly than true ones (*cf*. Table 3-8). By contrast, a crossover interaction was observed for the 'FN ≤ TN' group. As with the N400 for this group, the truth effect was, at least numerically, reversed between affirmatives and negatives. RTs were significantly longer to FA than to TA, and while FN and TN did not differ significantly, RTs appeared longer for FN. See Table 3-9 for all pairwise comparisons. Overall, the group differences in RT patterns closely matched the N400 variations.

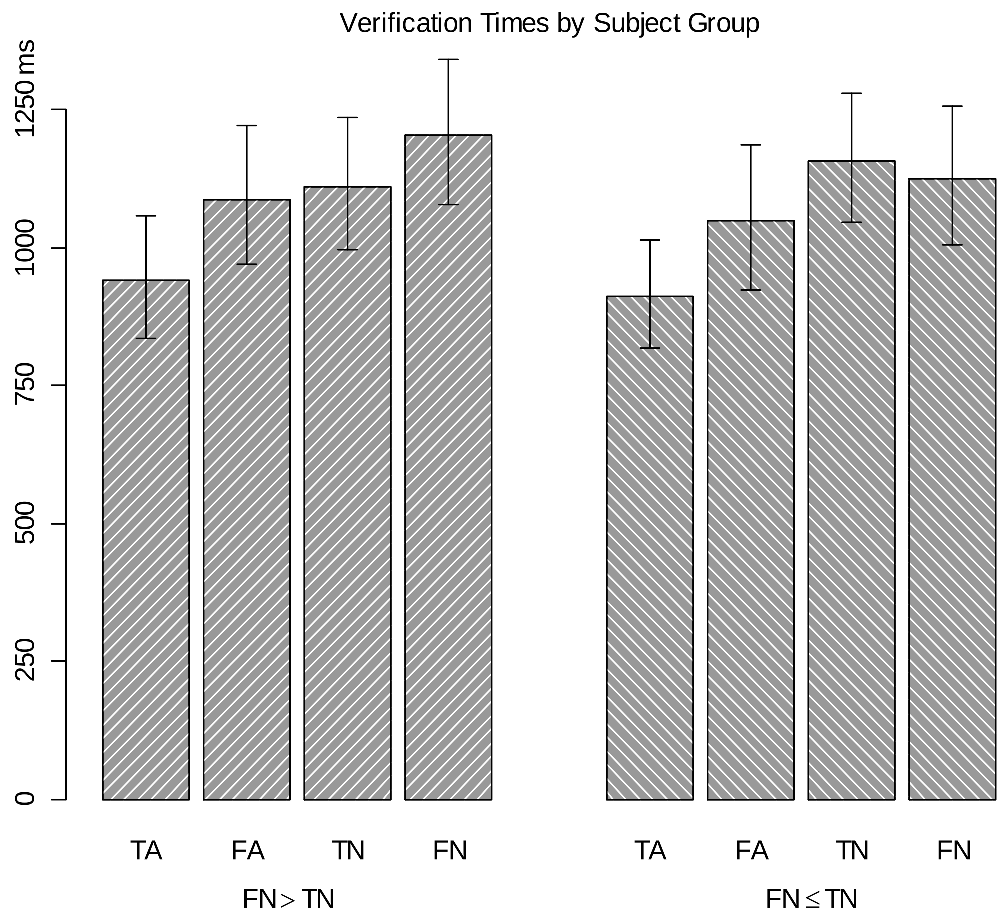


Figure 3-10. Verification times for the two subject groups in Experiment 1a. Error bars represent 95% confidence intervals. Means and standard errors were computed on by-subject averages of log-transformed data. Back-transformed values are shown. The group of subjects with larger N400s to FN compared to TN is shown on the left, the group with the opposite pattern on the right.

Table 3-8. Pairwise comparisons of RTs for the 'FN>TN' group. Raw *p* values are shown, and differences that are significant after Hochberg (1988) adjustment at the .05 level are marked with an asterisk (*).

	z	*p*	Significance
TA–FA	-7.13	<.001	*
TA–FN	-12.13	<.001	*
TA–TN	-8.14	<.001	*
FA–FN	-4.97	<.001	*
FA–TN	-1.03	.304	n.s.
FN–TN	3.92	<.001	*

Table 3-9. Pairwise comparisons of RTs for the subjects with a 'FN ≤ TN' N400 pattern. Raw p values are shown, and differences that are significant after Hochberg (1988) adjustment at the .05 level are marked with an asterisk (*).

	z	*p*	Significance
TA–FA	-5.33	<.001	*
TA–FN	-8.11	<.001	*
TA–TN	-9.22	<.001	*
FA–FN	-2.75	.006	*
FA–TN	-3.89	<.001	*
FN–TN	-1.14	.253	n.s.

Table 3-10. Results of the group comparisons on test scores. The Wilcoxon rank-sum statistic *W* and the exact *p*-value (corrected for the presence of ties) are reported.

		W	*p*
Print Exposure	ART	136.0	.640
	MRT	122.5	.977
Stroop	Neutral Time	127.5	.887
	Interference Time	88.5	.185
	Interference Cost	91.0	.219

3.1.3.4 Cognitive Tests

Table 3-10 shows the results of the group comparisons on the ART, MRT, neutral and interference Stroop times, as well as interference cost. No group differences were found to be reliable or even to approach significance.

3.1.3.5 Bias Sentence: Reading Times and Event-Related Potentials

Reading Times

Reading times for the bias sentence decreased over the course of the experiment [$F(1, 3832) = 337.23$, $p < .001$], but did not depend on the length of the sentences [$F(1, 3832) < 1$]. Importantly, group had a marginal effect [$F(1, 3832) = 3.23$, $p = .073$], with subjects in the ‘FN > TN’ group tending to take more time to read the bias (3098 ms) sentences than subjects in the ‘FN ≤ TN’ group (2651 ms).

Event-Related Potentials

Figure 3-11 shows the ERPs to the first 1600 ms[11] of the bias sentence. These ERPs looked quite different from ERPs time-locked to single words, as they were recorded while subjects read sentences presented as a whole on the screen. Except for the posterior P1, most sensory components, i.e. the frontal and posterior N1 and P2, appeared to be present however. After first positive peak, the ERPs grew increasingly negative, reaching a maximum around 400 ms at frontal, 500 ms at central, and 800 ms post sentence-onset at posterior sites. This maximum negativity was then followed by a positive-going trend that lasted almost until the end of the epoch (1800 ms), leveling off earlier at frontal than at posterior locations.

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[11] Approximately 10% of reading times were shorter than 1600 ms, that is, the subject had already stopped reading the sentence by the end of the epoch. A longer epoch would have contained an even higher percentage of such trials (15% at 1800 ms, 22% at 200 ms, etc.).

Beginning immediately at sentence-onset, the ERPs for the two groups started to diverge, with more negative-going waveforms in the 'FN > TN' group compared to the 'FN ≤ TN' group. In the 0-700 ms time-window, this effect was significant [$F(1, 30) = 4.20$, $p = 0.049$], and it was present across the scalp [group x electrode: $F(25, 750; \varepsilon = .069) = 1.35$, $p = .266$].

3.1.3.6 Summary of Group Comparions

In line with the sorting criterion, the two subject groups differed with respect to their N400 patterns: A main effect of truth but no truth x negation interaction was observed for the 'FN>TN' group; i.e., the same truth effect was found for affirmatives and negatives. In the 'FN≤TN' group, by contrast, the truth effect was reversed between affirmative and negative sentences. The RT results paralleled these N400 differences: RTs to FN were longer than those to TN in the 'FN>TN' group, while the opposite pattern was found in the 'FN≤TN' group. As for the overall sample, N400 and RT results went together.

No significant group differences were observed for any of the other ERP measures or Stroop and print exposure scores. The ERPs to the bias sentence, however, differed significantly between the groups, with larger negativities found in the 'FN>TN' group, who also tended to take more time to read the bias sentences.

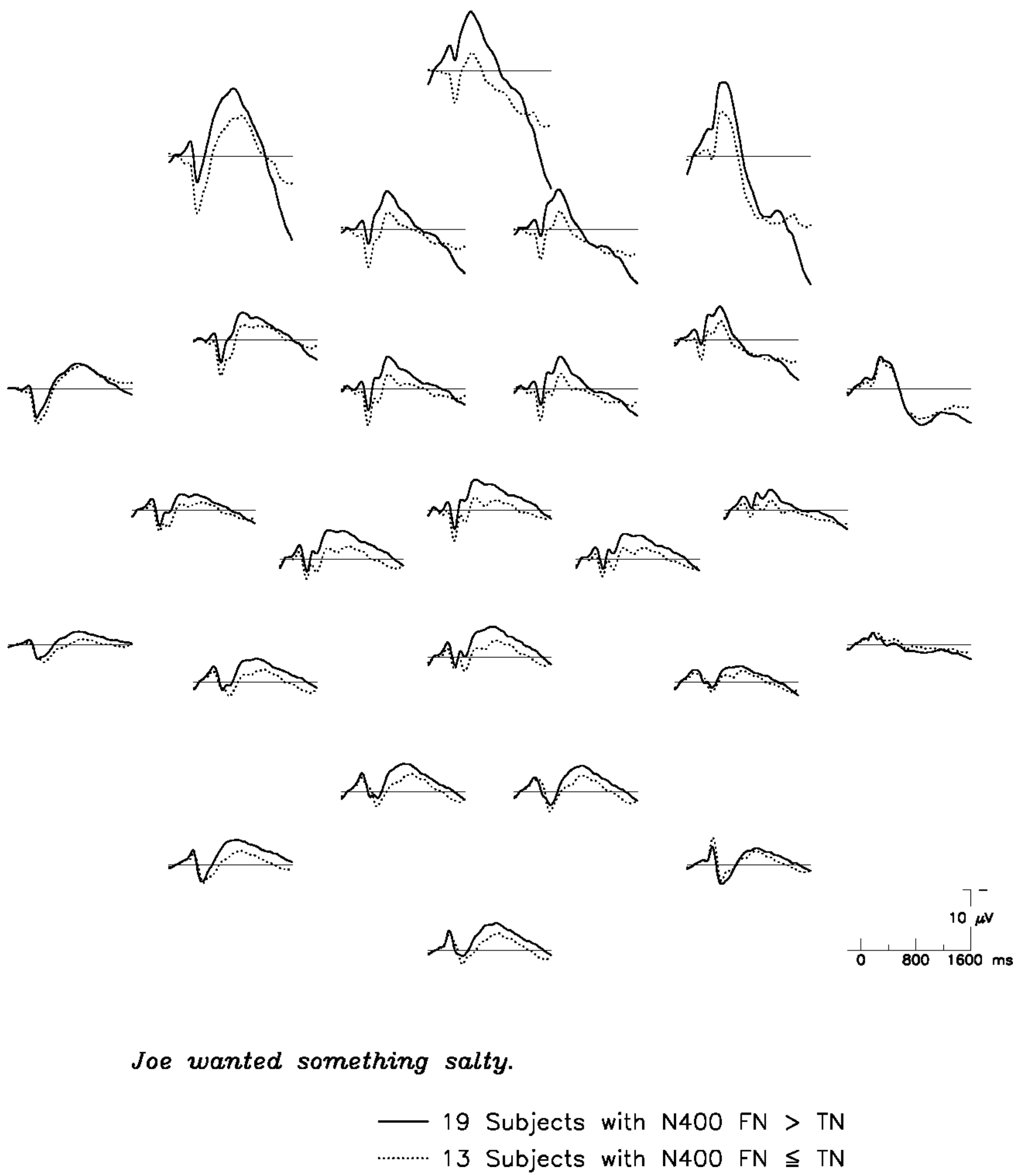

Figure 3-11. ERPs to bias sentences for Experiment 1a. Waveforms for the two subjects groups are plotted on top of each other.

3.1.4 Discussion

If negation was processed only after the embedded affirmative proposition, as Fischler et al. (1983) suggested, N400 amplitude to the sentence-final target should have depended strictly on the relationship between target word and bias sentence; it should have been impervious to negation. That is, we should have found no main effect of truth, but only a truth x negation interaction, with FA eliciting larger N400s than TA, but FN leading to smaller N400s than TN. Both related words (TA and FN) would be associated with smaller N400 amplitude than both unrelated ones (FA and TN). This was the result that Fischler and colleagues found when they used isolated affirmative and negative sentences, like *A robin is (not) a bird/vehicle*.

The present experiment, however, embedded target sentences in choice scenarios, allowing for the prediction of correct endings for both affirmative and negative sentences, and it revealed a very different data pattern: Overall, true sentence endings elicited smaller N400s than false ones, and while the truth effect failed to reach significance for negatives, it was the same direction as for affirmatives. The effect of truth thus dominated over the effect of relatedness with respect to N400 amplitude. Truth, in turn, was dependent on the presence or absence of negation, which leads to the conclusion that negation must have already played a role in the processing of the target word that is reflected in the N400. Negation must have been integrated in the representation of the target sentence *before* the processing of the embedded proposition – which included the final word – was completed. The hypothesis of early negation processing was thus corroborated in the pattern of the N400 data. In addition, verification times were also consistent with the N400 data, as true sentences had an RT advantage over false ones, in both affirmative and negative mode.

A closer look at individual data patterns, however, revealed significant variability in the target N400 as well as verification times for negative sentences: While the same N400 truth effect was found in affirmatives and negatives (i.e. no effect of relatedness whatsoever) in some subjects, others showed a pattern dominated by relatedness and not truth, with larger N400 to TN than FN. Furthermore, the subject group with a smaller N400 to TN compared to FN showed the same pattern for RTs, while the group with the reversed N400 ordering also had the reversed RT pattern.

One possible explanation of these differences is that one group of subjects did indeed integrate negation on-line, as soon as it was encountered, while the other group was characterized by delayed processing of negation. For example, subjects with higher cognitive capacity or linguistic skills might find it easier than those with lower abilities to process negation immediately. A comparison of the subject groups on a number of test scores, however, did not reveal any differences, thus failing to support this hypothesis. It is, of course, possible that the tests administered in this study did not measure the relevant abilities. Besides, the difference in negation processing might be a strategy that is not correlated with skill. We therefore cannot rule out the possibility that different subjects integrate negation at different points in time.

On the other hand, a different hypothesis found some support in the data. According to this hypothesis, subjects differed in the way they processed the bias sentence, which provided the information necessary to evaluate the truth of the target sentence. While presumably all subjects inferred the correct (affirmative) choice from the bias sentence, some may not have also committed the negative inference to memory. These subjects would then not be able to (quickly) update their expectations about the ending of the target sentence upon encountering the negation marker. Like Fischler et al.'s (1983) subjects, they would have no readily available alternative to plausibly complete the negative sentence.

In line with this hypothesis, the ERPs to the bias sentence did indeed differentiate the subject groups. While the functional interpretation of the sustained voltage difference is unclear, the significant effect does indicate some kind of processing difference at this critical stage. Furthermore, subjects in the group with consistent truth effects for affirmatives and negatives tended to take more time to read and process the bias sentence, which might reflect the increased effort associated with keeping the negative inference active in memory. Overall, these data are far from conclusive and difficult to interpret. They are, however, at least consistent with the idea that not only the information contained directly in the bias sentence but the inferences drawn from it play an instrumental role in the processing of the target sentence.

Additional ERP effects provided further, if hard to interpret evidence for early effects of negation on sentence processing. Most notably, the sentence segment following the negation marker elicited significantly more negative going ERPs than the same words in the affirmative sentence context. Negation must thus have been registered and affected subsequent processing. Its distribution likens this negation effect to the sustained left anterior negativity (LAN) that was found in response to sentences thought to place higher demands on working memory (Felser, Clahsen, & Münte, 2003; Fiebach, Schlesewsky, & Friederici, 2001; King & Kutas, 1995; Münte, Schlitz, & Kutas, 1998). The negativity found in the current experiment might thus reflect an increased working memory load associated with the processing of the negation marker, due for example to the retrieval of the correct ending for negatives. This result of the negative inference may be less readily available than the affirmative inference, as negative information tends to get backgrounded if not suppressed (cf. section 2.2.2).

Preceding the N400, the P2 to the target word showed sensitivity to negation, as targets in negative sentences elicited larger positivities than those in affirmative sentences. While this finding supports the idea that negation affected the processing of the target word, its interpretation is not clear. P2 effects have been linked to the matching of visual features, with larger P2s to stimuli containing the target feature (Luck & Hillyard, 1994). In the current experiment, however, the P2 varied only as a function of the context the word appeared in; it did not depend on any property of the target word or its relationship to the context. A different functional interpretation of the P2 may be more applicable. According to this proposal, the P2 reflects the selection of a target and/or the suppression of distractors (Bles, Alink, & Jansma, 2007; Melara, Rao, & Tong, 2002). If there is more competition, selection becomes harder and more suppression is needed; as a result, P2 amplitude increases. For the current experiment, an argument can be made that subjects generally had less strong expectations about the ending of negative sentences. So the target word had to be selected out of a larger set of candidates; there was more competition. The fact that no P2 differences were found between correct and incorrect targets is consistent with this idea, as both had to be selected from the same set of candidates; that is, they had the same number of competitors.

ERP effects in time-windows following the N400 did not directly bear on the main hypothesis, because these late components are usually thought to reflect conscious decision-making, rather than online sentence processing. Even so, the result pattern was at odds with a related claim by Fischler and colleagues (1983): They observed more positive ERPs to negative sentence endings after 700 ms post target onset and interpreted this effect as a delayed LPC to negative sentences, due to the processing of negation in a second step following the initial processing of the embedded proposition. The current experiment, however, revealed a much earlier LPC (between 400 and 600 ms), which was sensitive to sentence truth, followed by a slow wave that, like in Fischler et al. (1983), was more positive for negative sentence endings. Given that the correct decisions were reflected in the earlier LPC, it is unlikely that the slow wave in this experiment was an index of a second processing stage due to negation. Together with the other ERP and verification data, these findings thus strengthen the case against a delayed processing of negation.

3.2 Experiment 1b: Whole-Sentence Verification

The traditional approach to studying negation is based on a timed sentence-picture verification task. An affirmative or negative sentence is presented before, simultaneously with, or after a picture, and the subject is asked to decide whether the sentence is consistent with the picture. In the choice scenarios, the bias sentence together with the introduction fulfills the same function as the picture in the classic paradigm; it serves as the background against which the target sentence is verified. The current experimental paradigm, in which the target is the final sentence, is thus equivalent to presenting the picture before the sentence. This kind of situation has usually produced the RT pattern predicted by Clark's (1976) 'True' model: TA are verified faster than FA, but TN lead to longer RTs than FN. In Experiment 1a, however, a different pattern was found, with shorter RTs to true than to false sentences, for *both* affirmatives and negatives. There are two possible explanations for this discrepancy. One option is that the choice scenarios were more likely than pictures to make subjects anticipate the correct affirmative *and* negative sentence completion. The other possibility is that the way in which the final sentence was presented played an important role: In classic verification studies, the whole target sentence appeared at once, while it was presented word-by-word in Experiment 1a.

In the current experiment, subjects saw the same choice scenarios as in Experiment 1a, but the target sentence was presented as a whole. This experimental setup allowed us to determine whether the change in RT pattern was due to the stimuli alone, or whether the mode of presentation made a difference. If the appearance of a normal truth effect in negatives depended on word-by-word presentation, one would expect the classic RT pattern with a reversed truth effect for negatives if the same sentences were presented as a whole (i.e., in the present experiment). The same truth effect should be found in both affirmatives and negatives, however, if presentation mode did not matter.

3.2.1 Method

3.2.1.1 Subjects

Sixteen subjects (13 women) with a mean age of 20.8 years (range 18-26 years) participated for academic credit or a cash payment of $7/hour. All were right-handed native speakers of English with normal or corrected to normal vision and no history of neurological disorders.

3.2.1.2 Design and Materials

The same materials as in Experiment 1a were used.

3.2.1.3 Procedure

Subjects completed the ART, MRT, and Stroop as described for Experiment 1a. During the following experiment, they were seated approximately 50 cm from a computer screen. The instructions were to read the first two screens (containing the introduction and bias sentences) at their own pace, and then to decide as quickly as possible whether the final sentence was consistent with respect to the information in the preceding sentences. Before reading the experimental stories, subjects completed four practice trials.

At the beginning of each trial, a row of ten crosses was presented for 1000 ms. After a 200 ms blank screen, the introductory sentences were shown until the subject pressed a button. Then the introduction disappeared, and 200 ms later the bias sentence was presented, again until a button press by the subject. Two-hundred milliseconds later, a question mark appeared to signal the subject that she had to make a decision on the subsequent sentence. The question marked stayed on for 1000 ms, and after a 200 ms break, the target sentence was presented. It remained on the screen until the subject pressed a button to make the *True*/*False* decision. A new trial started after 1200 ms. The experiment consisted of six blocks. Subjects were told to take breaks between blocks if they felt the need. Typically, a subject completed the experiment in 25 to 40 minutes.

3.2.1.4 Data Analysis

The analysis of accuracy and response time data followed the same overall strategy as in Experiment 1a, with a data loss of about 10% due to elimination of outliers and incorrect responses. Since the final sentence was presented as a whole in this experiment, verification time was confounded with basic reading time, which is affected by sentence length. Negative sentences, which were one to two syllables longer than affirmative ones, should take longer to read and verify simply because of this difference in length. Length (in syllables) was therefore added as a predictor to the mixed effects analysis of RTs, which allowed for the assessment of negation effects after controlling for the number of syllables in a sentence.

Table 3-11. Pairwise comparisons for accuracy in Experiment 1b. Raw *p* values are reported, and asterisks (*) in the last column indicate statistical significance at the .05 level after Hochberg (1988) adjustment for multiple comparisons.

	Wald *z*	*p*	Significance
TA–FA	2.86	.004	*
TA–FN	1.64	.101	n.s.
TA–TN	-4.97	<.001	*
FA–FN	1.03	.302	n.s.
FA–TN	-2.72	.007	*
FN–TN	3.62	<.001	*

3.2.2 Results

With mean values of .181 (*SD* = .097) for the ART and .259 (*SD* = .155) for the MRT, print exposure scores in this study were equally low as those in Experiment 1a. Stroop scores were also very similar to those in the previous experiment: Subjects took 36.2 seconds (*SD* = 6.1 s), on average, to complete the neutral version and 55.6 seconds (*SD* = 10.1 s) for the interference version, corresponding to a 55% increase.

<u>Accuracy</u>

The overall percentage of correct responses was 92%. Thus, accuracy was still very high in this whole-sentence paradigm, although it was slightly lower than in Experiment 1a, where the final sentence was presented word-by-word. The left panel of Figure 3-12 shows the rates of correct responses by sentence type. These rates did not increase or decrease linearly over the course of the experiment [Wald $z = 0.43$, $p = .656$]. Negation did not have a significant main effect [Wald $z = 1.17$, $p = .242$]. Truth did [Wald $z = 2.71$, $p = .007$], but there was also a significant truth x negation interaction [Wald $z = -4.47$, $p < .001$], indicating that the truth effect differed between affirmative and negative sentences. TA were verified more accurately than FA, but for TN the rate of correct responses was lower than for FN (see Table 3-11 for all pairwise comparisons).

Response Times

Table 3-12 presents descriptive statistics for log-transformed RTs (on which inferential statistics were performed), and the right panel of Figure 3-12 shows a plot of back-transformed RTs by sentence type. Response times decreased over the course of the experiment [$F(1, 1727) = 81.35$, $p < .001$], and they increased with sentence length [$F(1, 1727) = 445.40$, $p < .001$]. Negative sentences took longer to verify than affirmative ones [$F(1, 1727) = 155.05$, $p < .001$]. There was also a main effect of truth [$F(1, 1727) = 4.44$, $p = .035$], but the significant truth x negation interaction [$F(1, 1727) = 68.90$, $p < .001$] indicated that the truth effect differed between affirmative and negative sentences: TA were verified faster than FA, but TN led to significantly longer RTs than FN (*cf*. pairwise comparisons in Table 3-13). This reversed truth effect for negatives was observed in 12 out of 16 subjects.

Table 3-12. Response times for Experiment 1b. The first row shows averages and standard deviations (in parantheses) based on all individual data points, which were the used in the mixed-model analysis. For comparison purposes, the second row presents the same statistics for traditional by-subject averages, the basis for Figure 3-12.

	TA	FA	TN	FN
Prior Averaging				
None	3.050 (0.140)	3.099 (0.143)	3.205 (0.142)	3.171 (0.148)
By-Subject	3.048 (0.074)	3.099 (0.087)	3.206 (0.080)	3.170 (0.076)

Table 3-13. Pairwise comparisons for verification times in Experiment 1b. Raw *p* values are reported, and asterisks (*) in the last column indicate statistical significance at the .05 level after Hochberg (1988) adjustment for multiple comparisons.

	z	*p*	Significance
TA–FA	-7.33	<.001	*
TA–FN	-11.18	<.001	*
TA–TN	-14.89	<.001	*
FA–FN	-4.81	<.001	*
FA–TN	-8.61	<.001	*
FN–TN	-4.45	<.001	*

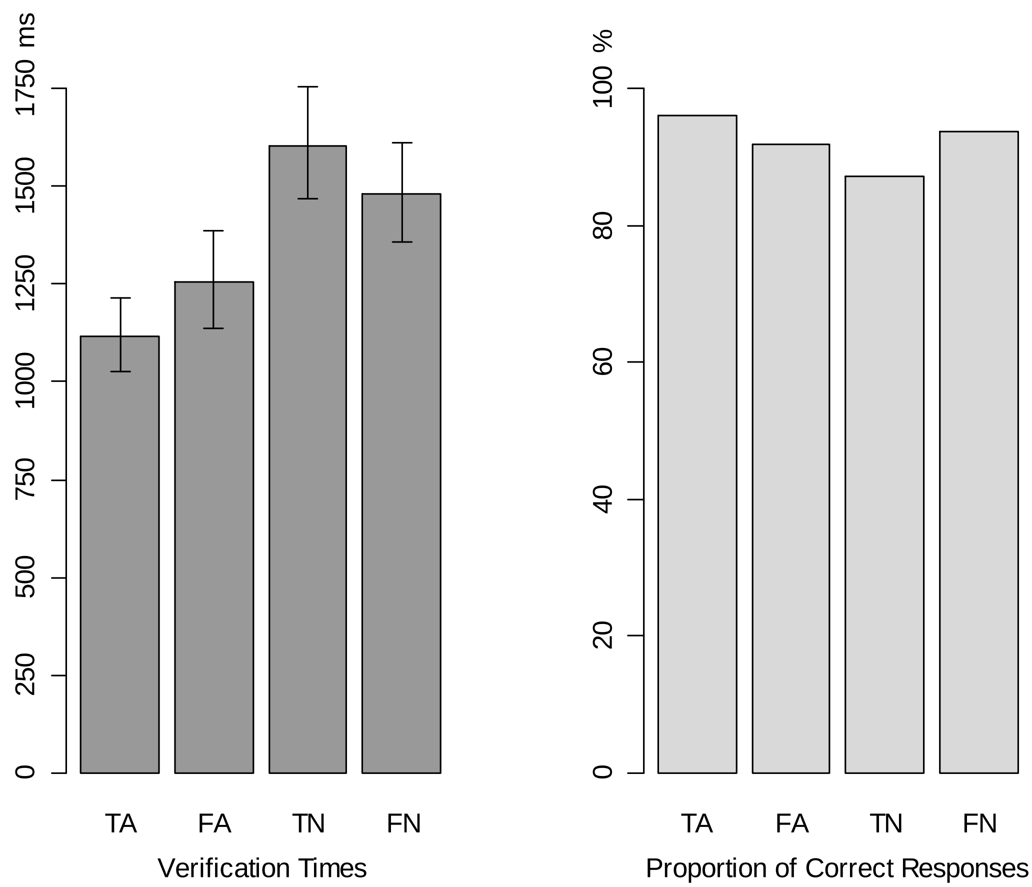

Figure 3-12. Verification times and accuracy in Experiment 1b. The left panel shows mean response times with 95% confidence intervals. Means and standard errors were computed on by-subject averages of log-transformed data. Back-transformed values are shown. The right panel shows the proportion of correct responses computed over all subjects and items.

3.2.3 Discussion

Experiment 1b produced a pattern of verification times that largely conformed to the findings of traditional picture-sentence verification studies and the predictions of the 'True' method (Clark, 1976): Affirmative sentences were verified faster than negative ones, and the two sentence types brought about opposite truth effects, with shorter RTs to TA than FA, but longer RTs to TN compared to FN. This outcome is markedly different from the RT results of Experiment 1a, where the target sentences were presented word-by-word. The hypothesis that the mode of presentation was critical in determining negation effects on RTs was therefore corroborated. Only when subjects read the final sentence word-by-word (i.e., in Experiment 1a), were they able to update their expectation about the correct sentence ending when encountering a negation marker. The relatively slow and gradual input method probably gave them enough time to do this: Typically, the final word didn't appear until approximately 1500 ms after the onset of *didn't* in word-by-word presentation. Then, upon encountering the final word, subjects verified the sentence in average time of 1034 ms. By contrast, subjects in the whole-sentence paradigm (Experiment 1b) read *and* verified the target sentence in 1349 ms on average. That is, they took only little more than 300 ms extra time to read the entire sentence prior to (or while) making the verification decision. This was apparently not sufficient to allow for negation to be (completely) processed prior to making the verification decision.

In addition to mere timing, there were arguably differences in processing load associated with the two presentation modes. Subjects who were shown the final sentence word-by-word could presumably process and integrate all information prior to the final word before verifying the sentence. By contrast, for subjects in the whole-sentence paradigm the task consisted of reading and integrating all the critical parts of the sentence as well as verifying it at more or less the same time, and the resulting multiple-task situation could interfere with the initial processing of negation. Anticipating the correct ending of a negative sentence required retrieving the negative inference made on the basis of the bias sentence. This negative inference was probably less active in working memory than the affirmative option, because negated concepts tend to be suppressed or backgrounded (*cf*. section 2.2.2). If too much attention had to be devoted to the processing of additional information, information could be lost from working memory (Cowan & Morey, 2007), and the backgrounded negative information would be more affected than the affirmative one. Additionally, the multiple-task situation could negatively affect the processing of negation and the retrieval of the negative information, as divided attention or the simultaneous performance of more than one task result in performance decline (cf. Pashler, 1994; Tombu & Joelicoeur, 2003). Both the loss of the negative inference from memory and the failure to retrieve it would bring about the same effect: The only information to which the target sentence could be compared was the affirmative situation, and in this case, the predicted RT pattern is the one found in Experiment 1b as well as numerous sentence-picture verification studies (Carpenter & Just, 1975; Clark & Chase, 1972; Trabasso et al., 1971). As it affects the timing of target sentence processing as well as the resources available for it, the presentation mode could thus have a marked impact on verification times. To the extent that an advantage of true over false negative sentences depends on the possibility to anticipate the correct ending of a negative sentence, finding this advantage appears to require not only the availability of this negative alternative in the context, but also a setting that allows the subject to use that information during the processing of the target sentence.

3.3 Experiment 1c: Word-by-Word Verification

The comparison of Experiments 1a and 1b demonstrated that the way in which target sentences are presented influences, if not determines the relative verification times for true and false negative sentences. Besides presentation mode, however, the two experiments also differed in other experimental variables. In Experiment 1a, the verification task was embedded in an ERP paradigm, which required participants to carry an electrode cap as well as control their body and eye movements. This was likely to affect the amount of attention or cognitive capacity subjects could dedicate to processing and verifying the choice stories. In addition, subjects in the two experiments received different instructions: While subjects in the whole-sentence verification study were asked to respond as quickly as possible, correctness was emphasized in the ERP study, and subjects were not given any timing instructions. In order to draw definite conclusions about the impact of presentation mode, uncontaminated by other experimental variations, it was therefore necessary to conduct a study that differed from Experiment 1b only in the way stimuli are presented, but not in other task demands or instructions. This was the purpose of Experiment 1c: Subjects completed a timed verification task without simultaneous EEG recordings, but the target sentence was presented word-by-word. It was expected that the RT pattern in this experiment would largely conform to that observed in Experiment 1a, with shorter RTs to TN than FN. Furthermore, as the overall processing load in a verification only paradigm was probably lower than in the ERP setting, it was also likely that the retrieval of the negative inference would be significantly facilitated. If that was the case, the truth effect for negatives might be as strong as that for affirmative sentences.

3.3.1 Method

3.3.1.1 Subjects

Sixteen subjects (14 women) with a mean age of 20.5 years (range 18-24 years) participated for academic credit or a cash payment of $7/hour. All were right-handed native speakers of English with normal or corrected to normal vision and no history of neurological disorders.

3.3.1.2 Design and Stimuli

The materials from Experiments 1a and 1b were used here as well.

3.3.1.3 Procedure

Test administration, instructions, and practice paralleled the procedures described for Experiment 1a and 1b.

As in Experiment 1b, a trial began with a row of ten crosses that was presented for 1000 ms and followed by a 200 ms blank screen. Next, the subject read the introduction and bias in a self-paced manner; the two screens were separated by a 200 ms break. Starting 1200 ms after the offset of the bias sentence screen, the final sentence was presented word-by-word with an SOA of 500 ms and a stimulus duration of 200 ms. The screen remained blank after the offset of the last word until the subject made his decision. A new trial started after 1200 ms. Subjects typically completed the experiment in 25 to 40 minutes.

3.3.1.4 Data Analysis

The analysis of accuracy and response time data followed the strategy described for Experiment 1a. Approximately 8% of trials were excluded from the statistical analyses because they were outliers or associated with an incorrect response.

3.3.2 Results

Mean scores on the ART and MRT were .169 (*SD* = .066) and .289 (*SD* = .127), respectively. Subject completed the neutral version of the Stroop in 35.3 s (*SD* = 4.7 s) on average. The took an average of 58.1 s (*SD* = 15.9 s) for the interference version, corresponding to a 65% increase. This sample of subjects was thus quite similar to the subjects who participated in Experiments 1a and 1b.

<u>Accuracy</u>

With 95% correct responses, overall accuracy was comparable to Experiment 1a, which also used word-by-word presentation. The right panel of Figure 3-13 presents the rates of correct responses by sentence type. It shows that affirmative sentences were verified correctly more often than negative sentences (Wald $z = -2.62$, $p = .009$). Truth did not have a significant main effect on accuracy [Wald $z = 1.19$, $p = .233$], and it did not interact with negation, either [Wald $z = 0.75$, $p = .451$]. There was also no reliable linear increase or decrease of error rates over the course of the experiment [Wald $z = 1.15$, $p = .252$].

<u>Response Times</u>

Table 3-14 presents descriptive statistics for the log-transformed data. The mixed-effects analysis revealed a significant decrease in RTs [$F(1, 1763) = 84.32$, $p < .001$] over the course of the experiment. There were also reliable independent effects of truth

[$F(1, 1763) = 69.88$, $p < .001$] and negation [$F(1, 1763) = 213.28$, $p < .001$]. Affirmative sentences were verified faster than negative ones, and true sentences led to shorter RTs than false ones. The left panel of Figure 3-13 shows the pattern that was found in 13 out of 16 subjects: TA were verified faster than FA, and TN faster than FN. That is, the direction of the truth effect was the same for affirmatives and negatives. Additionally, the absence of a significant truth x negation interaction [$F(1, 1763) = 2.36$, $p = .125$] indicated that the size of the truth effect did not differ reliably between affirmative and negative sentences.

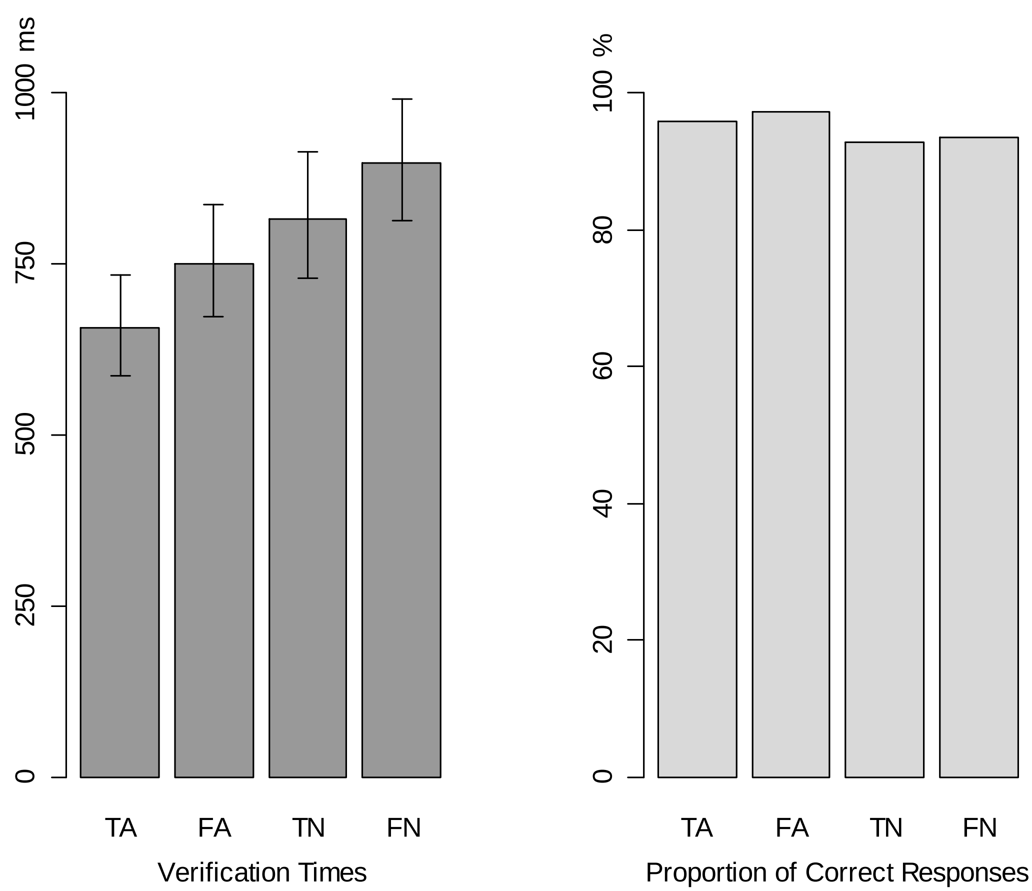

Figure 3-13. Verification times and accuracy in Experiment 1c. The left panel shows mean response times with 95% confidence intervals. Means and standard errors were computed on by-subject averages of log-transformed data. Back-transformed values are shown. The right panel shows the proportion of correct responses computed over all subjects and items.

Table 3-14. Response times for Experiment 1c. The first row shows averages and standard deviations (in parantheses) based on all individual data points, which were the used in the mixed-model analysis. For comparison purposes, the second row presents the same statistics for traditional by-subject averages, the basis for Figure 3-13.

	TA	FA	TN	FN
Prior Averaging				
None	2.818 (0.159)	2.875 (0.141)	2.913 (0.167)	2.954 (0.155)
By-Subject	2.817 (0.010)	2.876 (0.096)	2.912 (0.010)	2.953 (0.088)

3.3.3 Discussion

As expected, the pattern of verification times in the current experiment was largely similar to that observed in Experiment 1a, which also employed word-by-word presentation: For both affirmative and negative sentences, truth led to shorter RTs. This stands in contrast to the reversed truth effect observed in negative sentences in Experiment 1b, where target sentences were presented as a whole. As the current experiment differed from Experiment 1b only in way the target sentence was presented, the difference in relative RTs to true and false negative sentences can clearly be attributed to this difference. Word-by-word presentation gave subjects sufficient time to update their expectations about the correct ending of negative sentences, which led to the RT advantage of true over false sentences.

At the same time, there were also differences between the RT results of the two experiments with word-by-word presentation. In Experiment 1c, the truth effects in affirmative and negative sentences did not differ; there was no interaction between truth and negation. Subjects were equally good at anticipating the correct endings of affirmative and negative sentences. This was most likely possible because of the gradual presentation of the target sentence and the relatively low processing load with no interference from the experimental conditions necessitated by the ERP paradigm. By contrast, Experiment 1a produced a significant interaction between truth and negation, as the truth effect for affirmative sentences was larger than for negative sentences. That is, while the retrieval of the correct negative ending was *mostly* successful, it was not as consistent as that of the affirmative ending. With less capacity available for maintaining and retrieving the negative inference from the bias sentence, subjects were somewhat less likely to correctly adjust their expectation about the ending of a negative sentence.

3.4 Discussion of Experiment Set 1

The main goal of this series of experiments was to assess negation effects within the same sentence in which the negation occurred and to which it applied. More specifically, we were interested in whether negation could affect the fit of a lexical item that occurred later in that sentence. An earlier study by Fischler and colleagues (1983) failed to find effects of negation on the processing of a sentence-final word whose plausibility in the sentence (in terms of rendering the sentence true or false) depended on the presence or absence of negation. The same word was facilitated in both sentence modes, although it rendered the affirmative sentence true and the negative one false. These results were taken to imply that negation acted as an external operator that was processed only after the embedded affirmative proposition had been understood. We argued, however, that it was Fischler's use of isolated sentences that may have prevented the detection of negation effects. Without a context to provide alternatives to be denied, the most plausible ending for a negative sentence was the same one that was expected in the affirmative case. By contrast, Experiments 1a-c embedded the critical sentences in contexts that introduced two options, and the most plausible ending differed between the affirmative and the negative version. We therefore hypothesized that in both affirmatives and negatives, the ending that rendered the corresponding sentence true would be facilitated. That is, negation should affect which ending would be more expected.

Experiment 1a largely corroborated this hypothesis, as the N400 to true sentence endings was larger than that to false endings. This effect was significant for affirmative sentences, but not for negative sentences, although it pointed in the same direction. Importantly, the results showed that the fit of a word in the sentence *was* modulated by negation. Unlike in Fischler and colleagues' (1983) study, the same word was facilitated when it rendered the affirmative sentence true, but not when it was a false ending for the negative version of the sentence. In most subjects, the N400 was in fact even larger to FN endings than that to TN targets, while the same words showed the opposite pattern when they occurred as TA and FA, respectively, in affirmative sentences. A smaller group of subjects, however, showed a pattern more similar to the one Fischler found: The same words were facilitated in affirmative and negative sentences, with lower N400 amplitudes to TA compared to FA, and FN compared to TN. A comparison of these two subject groups revealed that the truth effect in negative sentences was correlated with aspects of the processing of the bias sentence. Subjects who showed facilitation of TN compared to FN tended to take more time to process the bias sentence than subjects with the opposite pattern. ERP differences between the groups also suggested that the processing of the bias sentence may have affected the target N400.

Response times in Experiment 1a followed a pattern similar to the N400, as sentences that elicited larger target N400s led to longer RTs as well. The RTs showed an additional main effect of negation with longer RTs to negative sentences, but the truth effects within each sentence mode paralleled those found for the N400. This was the case for the data from the entire sample as well as the subject groups. The subjects whose N400 was smaller to true than to false targets in both affirmatives and negatives also verified true sentences faster than false ones in both sentence modes. Conversely, the subjects with reversed truth effects for negatives on the N400 also tended to show longer RTs to TN than FN. Overall, the factors that determined N400 amplitude, i.e. the combination of sentence truth and mode as well as the processing of the bias sentence, appeared to have similar effects on RTs.

Experiments 1b and 1c demonstrated that RT patterns also depended on the manner in which the target sentence was presented. The advantage of TN over FN was only observed when word-by-word presentation was employed, that is in Experiments 1a and 1c. By contrast, when the whole target sentence appeared at once – in Experiment 1b – truth effects were reversed between affirmatives and negatives, with shorter RTs to FN compared to TN. A slower, gradual presentation of the target sentence thus seemed to favor true endings in negative sentences, while a presentation mode that encouraged quick reading of the target sentence favored the ending that rendered the affirmative sentence true (and the negative sentence false). In addition, overall processing load appeared to affect the result patterns, as Experiment 1c produced equal truth effects in both sentences modes, while Experiment 1a, which included the ERP procedure, resulted in a weaker truth effect for negative sentences.

In sum, negation can have an effect on the processing of lexical items in its scope. It can reduce the facilitation of a word that would fit in the affirmative version of a sentence and redirect attention to a concept that is more appropriate in the negative context. The extent to which these effects can be observed, however, depends strongly on experimental conditions as well as strategies employed by individual subjects. In the remainder of this chapter, we will therefore attempt to provide a general account of the processes that gave rise to the various data patterns observed in this series of experiments.

Classic models of picture-sentence verification (e.g., Carpenter & Just, 1975; Clark, 1976; Trabasso et al., 1971) proposed that response time differences were due to matches or mismatches between the representations of the sentence and picture to be compared. For the paradigm employed in the current experiments, the equivalent of picture and sentence would be the expected sentence-final word and the one that was actually presented. An account of N400 effects, however, does not need to invoke an active comparison process in several stages as the semantic verification models did. Instead, one can think of the effect as facilitation; the target word is primed by the preceding context and the inferences that could be drawn from it. Indeed, the basic variable that is thought to give rise to differences in N400 amplitude to the target word is its fit within the context, i.e. how expected a word is or to what extent it is primed by the preceding sentence and discourse context. The strong similarities between N400 and RT data in Experiment 1a suggest that not only N400 amplitude is modulated by these priming processes, but also RT. This is not surprising as primed words are generally processed faster, thereby speeding up RTs to the entire sentence as well. Of course, RTs are also affected by other variables, like the processing of negation itself, which slowed verification times. This effect may be located in conscious decision making, which is not part of sentence processing per se, or it may be due to the construction of mental models of the sentence information, which most likely also occurs post-sententially (cf. Kaup, 2006; Kaup & Zwaan, 2003; Kaup, Zwaan et al., 2007). The focus of interest here, however, is the effect of negation on the processing of words within the same sentence, i.e., the N400 and RT differences (within one sentence mode) that can be attributed to the fit between the expected and the actual target word. Given that the target words do not differ between conditions, the question is then how expectations about the target vary as a function of experimental manipulations.

Which word best completes the target sentence depends on the preceding discourse, especially the bias sentence. The bias sentence, which provides information about a character's preferences (e.g., *Joe wanted something salty*.), affords two inferences, one about the option that is chosen (*pretzels*) and, in turn by not-both elimination, one about the alternative that is not chosen (*not cookies*). Both inferences should be made routinely during reading (Lea & Mulligan, 2002). The result of one of the two inferences completes the sentence so as to make it true, and it should therefore be more expected assuming time and resources. In the case of an affirmative sentence (*So he bought the…*), the affirmative inference (*pretzels*) constitutes the correct completion, while a negative sentence (*So he didn't buy the…*) is completed correctly by the negative inference (*cookies*).

Under optimal conditions, i.e., if the inferences were made and kept accessible in working memory, and if sufficient time and processing capacity are available, subjects should be able to adjust their expectations about the sentence ending and anticipate the content of the appropriate inference depending on whether the target sentence is affirmative or negative. Consequently, true endings should have an equal advantage over false ones for both sentence types. This is, in fact, the result pattern observed for RTs in Experiment 1c. In this experiment, target sentences were presented word-by-word, and subjects had a single task: to judge the consistency of the stories. That is, subjects had both the time and the processing resources available to retrieve the correct ending from working memory while reading the target sentence, whether it was affirmative or negative. So the truth effect was of similar size in both sentence modes.

Under less optimal conditions, the retrieval of the correct ending may be more difficult. An increase in processing load or time pressure will have different effects in affirmative and negative sentences, however. In general, the affirmative inference is by default more activated than the negative one, as negation directs attention away from a concept to an alternative, in this case from the negative to the affirmative inference. If the target sentence is also affirmative, this default does not have to be changed, as the more activated affirmative inference is the correct ending that should be predicted. No particular processing resources are therefore needed in this case, and a higher load should have no effect. When the target sentence turns out to be negative, however, the expectation needs to be updated. This involves retrieving or activating the backgrounded negative inference, which may in fact necessitate sufficient time as well as processing capacity. Without enough time or resources, subjects may either fail to retrieve the correct ending for the negative sentence on at least some trials, or activate it only partially. The FN ending, which is the word that would make the affirmative sentence correct, thus remains, at least some times or to some extent, activated. As a result, the TN will be less and the FN more facilitated. The truth effect in negatives will be smaller than in affirmatives, and it may even be reversed, with an advantage of FN over TN.

These changes in truth effect for negatives were observed in Experiments 1a and 1b. In Experiment 1b, where the entire target sentence was presented at once, the truth effect was indeed reversed. As the presentation mode encouraged subjects to read the sentence as quickly as possible, time pressure and processing demands increased. Subjects failed to retrieve the correct ending for negative sentences before encountering the target word itself, and as a result the FN was processed faster than the TN. In Experiment 1a, the differences in both processing load and truth effect for negatives were more subtle. The target sentence was presented at the same rate as in Experiment 1c, but the requirements of the ERP paradigm probably introduced extraneous task demands, thereby diverting processing resources from the main task, the comprehension and verification of the stories. Consistent with this relatively minor interference, the truth effect in negatives was not reversed, but smaller than in affirmatives. The advantage of TN over FN was not as big as that of TA over FA, which is expected if subjects fail to retrieve the TN ending on some trials or if they do not completely shift the focus away from the affirmative inference to the correct negative ending.

Even when processing load is not particularly high, as in Experiment 1a, some subjects may not at all update their expectations about the target as a function of negation. As described before, this change in expectation can be viewed as the retrieval of the negative inference from the bias sentence, which tends to be backgrounded due to the suppressive effect of negation. Lea and Mulligan (2002) have even shown that the result of such a negative inference may not receive or retain any additional activation. Remembering the negative inference is useful in the current paradigm, however, as it allows for the prediction of the correct ending of negative sentences and presumably easier verification. Subjects may therefore attempt to focus some attention on the negative inference and keep it in working memory. Yet, some of them may not make this conscious effort, either because they are not able to or because they choose a different strategy. They should therefore not activate the negative inference, which will make it impossible for them to retrieve the information when encountering the negation marker. Like the participants in the whole-sentence presentation paradigm, these subjects should therefore show a reversed truth effect for negatives. In Experiment 1a, a subgroup of subjects produced such a pattern for both N400 amplitude and RTs, although they read the stories under the same conditions as the other group, who showed an advantage of TN over FN. They did, however, spend less time processing the bias sentence, which is consistent with the idea that they may not have activated the negative inference in the first place.

In sum, Experiments 1a has demonstrated that negation can lead to differences in the processing of upcoming information, and the entire series of experiments has documented that the negation effects are affected by experimental conditions as well as subject variables. The effect of negation on the processing of subsequent words can be explained by changes in a subject's expectation about what these words are going to be. If the actual word matches the expectation, its processing will be facilitated. A change in expectation requires the activation of a suitable alternative, which in the case of negation will usually have to be derived from the discourse context. In addition to being in principle available in the context, the information must of course also be accessible to the subject. That is, the appropriate inference has to be made and kept active in memory, and the subject must have sufficient time and processing resources to retrieve the information. Given all these conditions, a negation marker should cause a subject to change her expectations about subsequent sentence elements. Experiments 1a-c have established the possibility of detecting these intra-sentential negation effects via behavioral and brain responses.

CHAPTER 4

NEGATION IN A NEGATIVE CONTEXT

In Experiment Set 1, the bias sentence provided information about a character's preferences (e.g., *something salty*) and thereby suggested which option that character was likely to pick (*pretzels*). As there were only two possibilities, it also allowed us to infer which option would most likely not be chosen. The result of this inference, however, was a negated concept (*not cookies*) and therefore subject on some accounts to suppression (Lea & Mulligan, 2002); that is, it would be relatively less activated than the affirmative inference. In addition, the lack of any reference to the negative inference in the bias sentence probably facilitated its backgrounding. While the correct affirmative sentence ending was directly related to various words in the bias sentence, nothing alluded to the negative ending, which therefore may not have been very prominent from the outset.

The relative prominence of affirmative and negative information (before taking suppression into account) will shift, however, if the bias sentence is itself negative, as in Example (1).

(1) *Negative bias*
Joe didn't want anything sweet.

In this case, the bias sentence mentions information referring to the correct negative ending (2iv), while the correct outcome of an affirmative (2i) can only be inferred logically.

(2) *Target sentence*

i.	So he bought the pretzels.	(TA)
ii.	So he bought the cookies.	(FA)
iii.	So he didn't buy the pretzels.	(FN)
iv.	So he didn't buy the cookies.	(TN)

The negative ending may still get inhibited, but the residual activation should be greater given that baseline activation was higher. TN would thus be more facilitated in this case than in the affirmative bias paradigm, and the truth effects for affirmatives and negatives would consequently be more similar. In fact, suppression may not be obligatory if the negated information is useful in establishing discourse coherence (Giora, 2006), which it arguably is in the choice scenarios. If suppression is minimal, one might even find that TNs are more facilitated than TAs, and the difference between TN and FN is larger than that between TA and FA.

This second set of experiments allowed us to assess these predicted outcomes, as it employed stories with negative bias sentences in the same experimental paradigms used in Set 1. The first goal was to replicate the negation effects observed in the previous series of experiments. That is, negation should again affect which sentence ending would be more expected, and the strength of this effect should vary with task requirements. In addition, we anticipated an overall stronger effect of negation on target expectations, as reflected in a stronger processing advantage of TN relative to FN. The main reason for expecting this increased truth effect for negatives was, as just mentioned, that negated concept would be more accessible given that the bias sentence referred to it directly. Furthermore, the negation in the target sentence also would be easier to process given that it was primed by the negative bias sentence. Research on syntactic priming has shown that the production or comprehension of a particular syntactic structure is facilitated if the same structure was used in the preceding sentence (Bock, 1986; Branigan, Pickering, & McLean, 2005)[12]. For the negative sentences in the present experiments, this means that the negation marker may be integrated faster into the representation of the target sentence so to have an earlier and therefore perhaps stronger effect on the processing of subsequent information in the sentence.

4.1 Experiment 2a: Event-Related Potentials

Experiment 2a employed the negative bias stimuli in the same ERP paradigm as its affirmative bias version, Experiment 1a, and the primary measure of interest was the amplitude of the N400 to the final word of the target sentence. The two presumed determinants of the target N400, i.e. the target word's relatedness to the bias sentence as well as its fit in the final sentence, were combined differently than in the affirmative bias experiment, however, which should lead to different pattern of results.

In Experiment 1a, TA endings received facilitation from both the relatedness and sentence congruency factors, as they were both true and lexically related to bias sentence words; FA targets were both false and unrelated. For negative sentences, on the other hand, the contrast between true and false endings was not as strong, because both TN and FN were facilitated by one of the two factors: TN endings were true, but FN endings were related to the bias. The difference between TA and FA was therefore expected to be larger than that between TN and FN, and the N400 and RT data conformed to this pattern.

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[12] None of the studies on syntactic priming used negative structures, perhaps because of the correlation between syntax and semantics inherent to negation.
The status of syntactic priming in pure comprehension paradigms is also debated. The effects appear to be less reliable than in production, and many studies have found effects only when the lexical item used in the structure was repeated (Branigan et al., 2005; Pickering & Traxler, 2004), although recent studies have succeeded in detecting syntactic priming effects in comprehension without repeated lexical items (Fedorenko & Gibson, 2005; Thothathiri & Snedeker, submitted). In any case, the crucial lexical item *not* has to be repeated in negation.

The combination of relatedness and truth lead to different predictions for the current experiment. Here, negatives are expected to show a large difference, given TN targets were related to the bias and true, while FNs were not only unrelated but false. TAs were true and unrelated, and FAs false but related; so the difference between the two affirmatives is expected to be smaller. These predictions, however, ignore the potential inhibitory effect of negation in the bias sentence as well as the importance of the inferences that can be drawn from that sentence.

In the discussion of Experiment 1, we suggested that the bias sentence afforded both an affirmative and a negative inference, and that the negative information tended to be backgrounded, so as to be less available to prime the correct sentence ending. The same general mechanisms would apply here, but with somewhat different effects because of the different structure of the sentence material. Since the information in the bias sentence itself is negative, the negative inference follows directly, while the affirmative one has to be derived logically via or-elimination. Or-elimination occurs routinely during reading, and the result of the inference gets activated (Lea & Mulligan, 2002). In the current experiment, the result of this affirmative inference would be the correct ending of the affirmative target sentence. Despite not being referred to in the bias sentence, the TA ending would thus be facilitated due to the affirmative inference. By contrast, the result of the negative inference would be inhibited along with the negated concepts in the bias sentence related to the TN ending. The TN's strong facilitation predicted from the truth and relatedness factors combined would thus be diminished due to negation-induced suppression. The suppression of negative information does not appear to be complete, however, as the results of Experiment 1a suggested that subjects could keep negative information active. In the current experiment, this would be even more likely, as the negative information is explicitly mentioned and thereby foregrounded in the bias sentence.

Consideration of all these factors allows for refined predictions: As in Experiment 1a, true sentence endings are expected to elicit smaller N400 amplitudes than false ones. Also, due to the effects of inferences and the suppression of negative information, the truth effect should again be larger in affirmative compared to negative sentences. However, because of the direct reference to negative information in the bias sentence, the truth effect for negatives should be stronger here than it was in Experiment 1a; i.e., it should at least be statistically significant. Overall, the N400 data pattern is thus expected to be similar to that observed in Experiment 1a, but with a larger difference between TN and FN.

RT data should parallel the N400 results, as they did in Experiment 1a. The negativity associated with verbs in negative sentences was also expected to recur here, and false endings should again elicit larger LPCs than true endings. As in all previous experiments, behavioral measures were recorded in order to account for potential variability among subjects.

4.1.1 Method

4.1.1.1 Subjects

Twenty-four subjects (14 women) with a mean age of 20.1 years (range 18-29 years) participated for academic credit or a cash payment of $7/hour. All were right-handed native speakers of English with normal or corrected to normal vision and no history of neurological disorders.

Table 4-1. Sample stimuli for Experiment Set 2 (negative bias). All bias-target combinations and the resulting experimental sentence types are shown.

		During his long flight Joe needed a snack. The flight attendant could only offer him pretzels and cookies. Joe didn't want anything… sweet.	salty.
So he bought the…	pretzels.	True Affirmative (TA)	False Affirmative (FA)
	cookies.	False Affirmative (FA)	True Affirmative (TA)
So he didn't buy the…	pretzels.	False Negative (FN)	True Negative (TN)
	cookies.	True Negative (TN)	False Negative (FN)

4.1.1.2 Design and Materials

The same test materials as in Experiment Set 1 were used here. The experimental stimuli were also identical, except that the bias sentences were changed into negatives. As a result, the association between the bias-target relatedness and truth was reversed with respect to Experiment Set 1. For instance, an affirmative sentence ending in a word that was lexically related to the bias sentence (e.g., sweet – cookies) was true in Experiments 1a-c, but false in this one, as demonstrated in the example in Table 4-1.

4.1.1.3 Procedure, EEG Recording, and Data Analysis

The procedures for testing, stimulus presentation, EEG recording, and data analysis specified for Experiment 1a were followed here as well. The only change concerned the selection of ERP time-windows for analysis: In this experiment, no measurements were taken in the 150-200 ms time-window. Instead, mean amplitudes were computed for a window ranging from 50 to 150 ms (N1) post word onset and submitted to statistical analyses. Nine percent of target epochs, 2% of verb ERP trials, as well as 5% of the RT data were lost to elimination of incorrect responses and outlier or artifact removal.

4.1.2 Results

Subject's test results resembled those found in Experiments 1a-c. Mean ART and MRT scores were .188 (*SD* = .064) and .309 (*SD* = .099), respectively. On average, subjects took 35.3 s (*SD* = 4.3 s) to complete the neutral part of the Stroop, and 55.4 s (*SD* = 11.0 s) for the interference version, that is approximately 56% more time.

4.1.2.1 Verification

<u>Accuracy</u>

With 96% correct responses, overall accuracy was again comparable to that observed in Experiments 1a and 1c, which also used word-by-word presentation. The right panel of Figure 4-1 shows accuracy rates by sentence type, but little variation is apparent. Accordingly, the statistical analysis found neither significant main effects for truth [Wald $z = 1.46$, $p = .145$] or negation [Wald $z = -0.55$, $p = .581$] nor a significant truth x negation interaction [Wald $z = -0.39$, $p = .700$]. Furthermore, there was no reliable linear change in error rates over an experimental run [Wald $z = 1.62$, $p = .105$].

<u>Response Times</u>

RTs decreased over the course of the experiment [$F(1, 2745) = 176.55$, $p < .001$]; they varied by sentence type. The left panel of Figure 4-1 presents these RTs in milliseconds, and Table 4-2 contains descriptive statistics for the log-transformed values on which the analyses were based. The data pattern was very similar to that found in Experiment 1a. Affirmative sentences led to shorter RTs than negative ones [$F(1, 2745) = 187.99$, $p < .001$], and true sentences were verified faster than false ones [$F(1, 2745) = 66.12$, $p < .001$]. The significant truth x negation interaction [$F(1, 2745) = 31.93$, $p < .001$] indicated that the truth effect was smaller for affirmatives than for negatives: It did not quite reach significance for negatives , while it was reliable for affirmatives (*cf*. Table 4-3). In Experiment 1a, by contrast, the truth effect was significant for both affirmatives and negatives. This difference between the two experiments was most likely *not* due to more between-subject variability, as only 29% of subjects (7/24) in the current experiment showed a reversed truth effect for negatives as opposed to 42% (13/32) in Experiment 1a. This lower variability should have facilitated the detection of a reliable difference. The failure to do so may be due to the difference in sample size, as Experiment 1a included 50% (eight) more subjects.

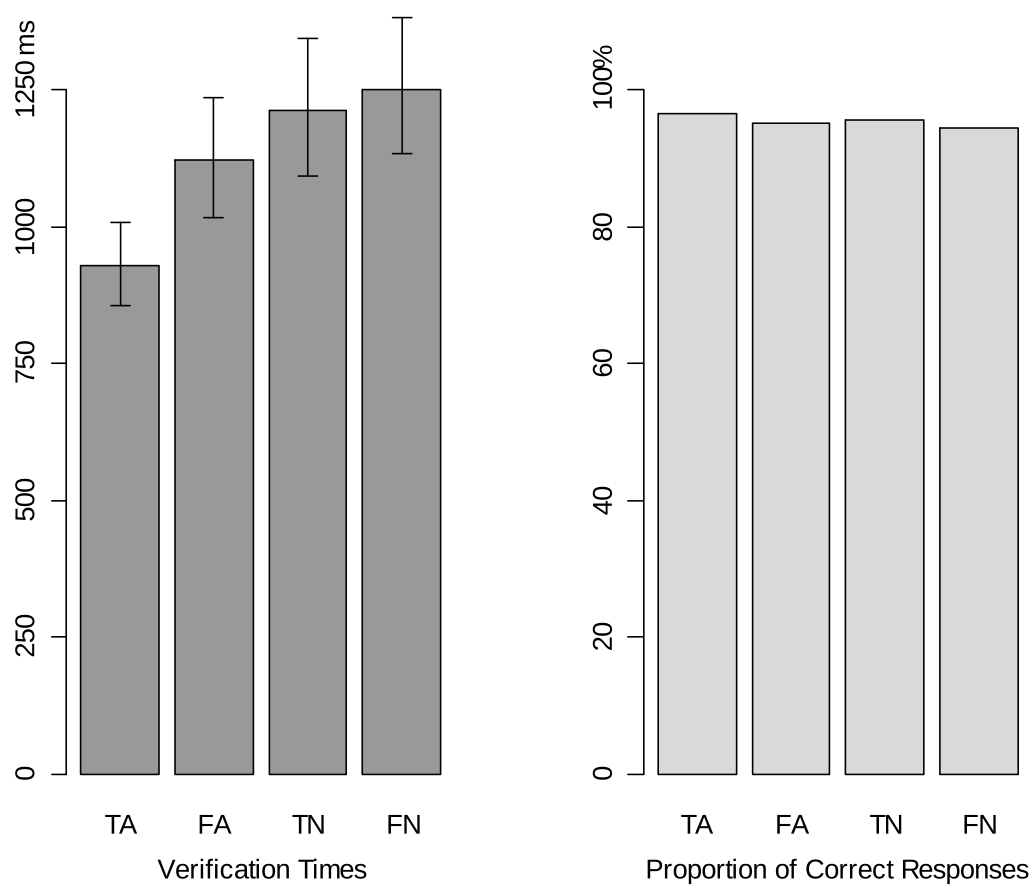

Figure 4-1. Response times and accuracy for Experiment 2a. The left panel shows mean response times with 95% confidence intervals. Means and standard errors were computed on by-subject averages of log-transformed data. Back-transformed values are shown. The right panel shows the proportion of correct responses computed over all subjects and items.

Table 4-2. Response times for Experiment 2a. The first row shows averages and standard deviations (in parantheses) based on all individual data points, which were the used in the mixed-model analysis. For comparison purposes, the second row presents the same statistics for traditional by-subject averages, the basis for Figure 4-1.

	TA	FA	TN	FN
Prior Averaging				
None	2.969 (0.181)	3.049 (0.175)	3.083 (0.203)	3.099 (0.197)
By-Subject	2.968 (0.089)	3.050 (0.105)	3.084 (0.112)	3.098 (0.109)

Table 4-3. Pairwise comparisons of RTs in Experiment 2a. Raw p values are shown, and the right-most column indicates whether the comparison is significant at the .05 level after Hochberg (1988) adjustment, with a star (*) indicating significance.

	z	*p*	significance
TA–FA	-9.75	<.001	*
TA–FN	-15.40	<.001	*
TA–TN	-13.71	<.001	*
FA–FN	-5.64	<.001	*
FA–TN	-3.93	<.001	*
FN–TN	-1.73	.083	n.s.

4.1.2.2 Event-Related Potentials

Verbs

As in Experiment 1a, verbs in negative sentences elicited more negative ERPs between 100 and 900 ms after word onset than verbs in affirmative sentences [$F(1, 23) = 90.77$, $p < .001$]. The size of this effect varied as function of electrode site [$F(25, 575; \varepsilon = .154) = 15.44$, $p < .001$], and the distribution was similar to that observed for the same effect in Experiment 1a. As is apparent in Figure 4-2, the negativity was larger at anterior [$t(23) = 2.54$, $p = .018$] and central locations [$t(23) = -5.88$, $p < .001$] compared to posterior sites, and was more pronounced at medial [$t(23) = -5.86$, $p < .001$] compared to lateral channels. Truth had no reliable effect on these ERPs, neither as a main effect nor in an interaction [all *F*s <1].

Sentence-Final Targets

The grand average ERPs to target words, presented in Figure 4-3, showed the typical visual sensory components. At the most posterior sites, the P1 peaked around 100 ms and the N1 at approximately 170 ms post word onset, and over fronto-central electrodes, the N1 had a peak at around 100 ms and the P2 at approximately 210 ms after word onset. In contrast to Experiment 1a, where the most early sensitivity to the experimental manipulations, namely negation, was found in the P2 time-window, the P2 in this study was unaffected by negation. At posterior channels, however, ERPs to true and false sentences appeared to diverge shortly after word-onset.

The posterior P2, with a peak at around 290 ms, was visible only for TA, TN, and FN. In FA it was probably overshadowed by the onset of a pronounced N400, which peaked earlier at more frontal channels (around 300 ms) than at posterior ones (360 ms). The other conditions also diverged between 200 and 400 ms, but only the ERP to FN showed a clear N400 overlapping the posterior P2. The N400 to false endings was followed by a positive-going deflection at all electrode sites. An LPC effect with a larger positivity to false than true endings between 400 and 600 ms, however, was visible only at mostly posterior (but non-central) channels. Toward the end of the epoch (after about 600 ms), ERPs to false endings were again more negative than those to true endings, mostly at central and right scalp locations.

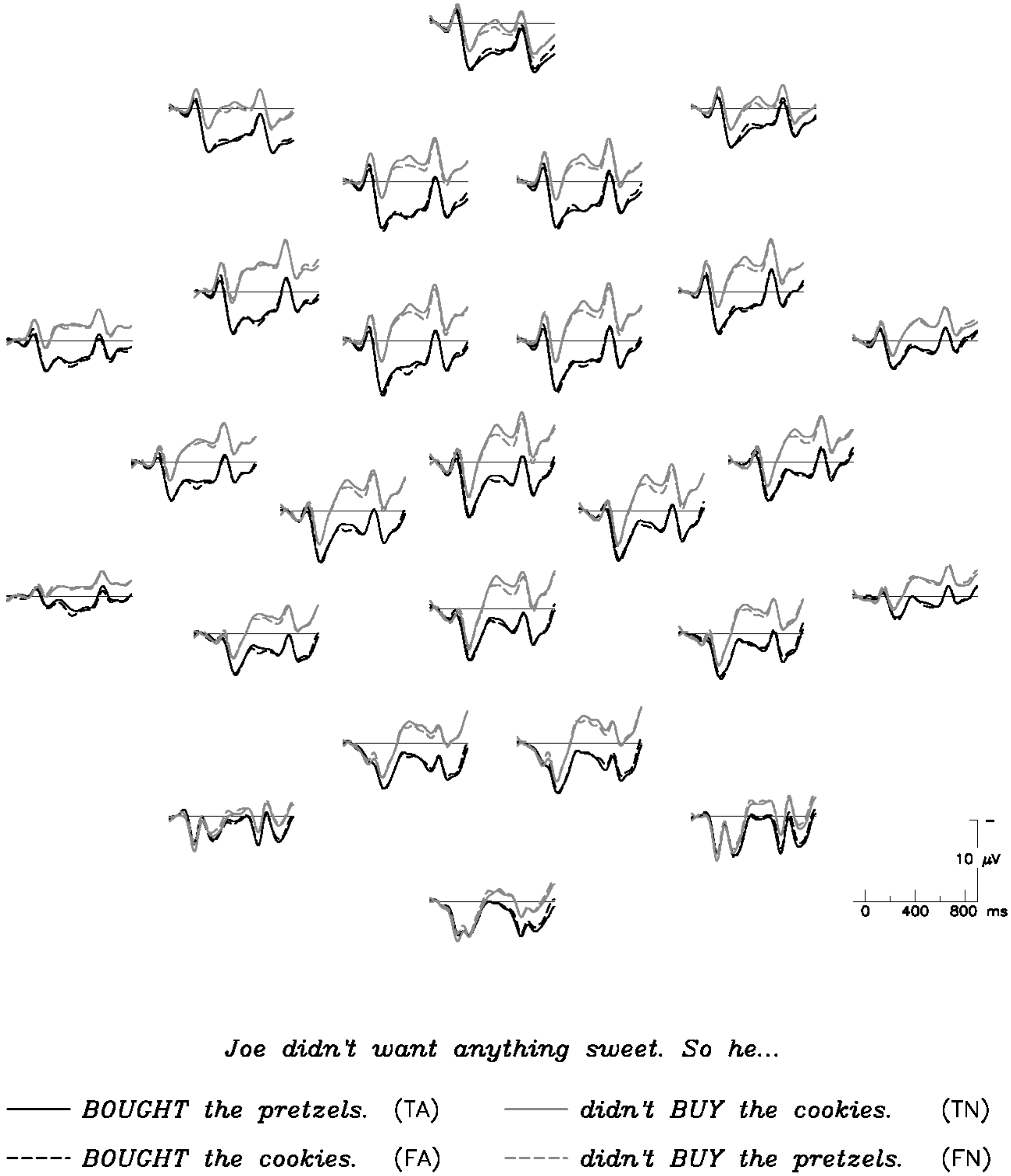

Figure 4-2. ERPs to final-sentence verbs in Experiment 2a.

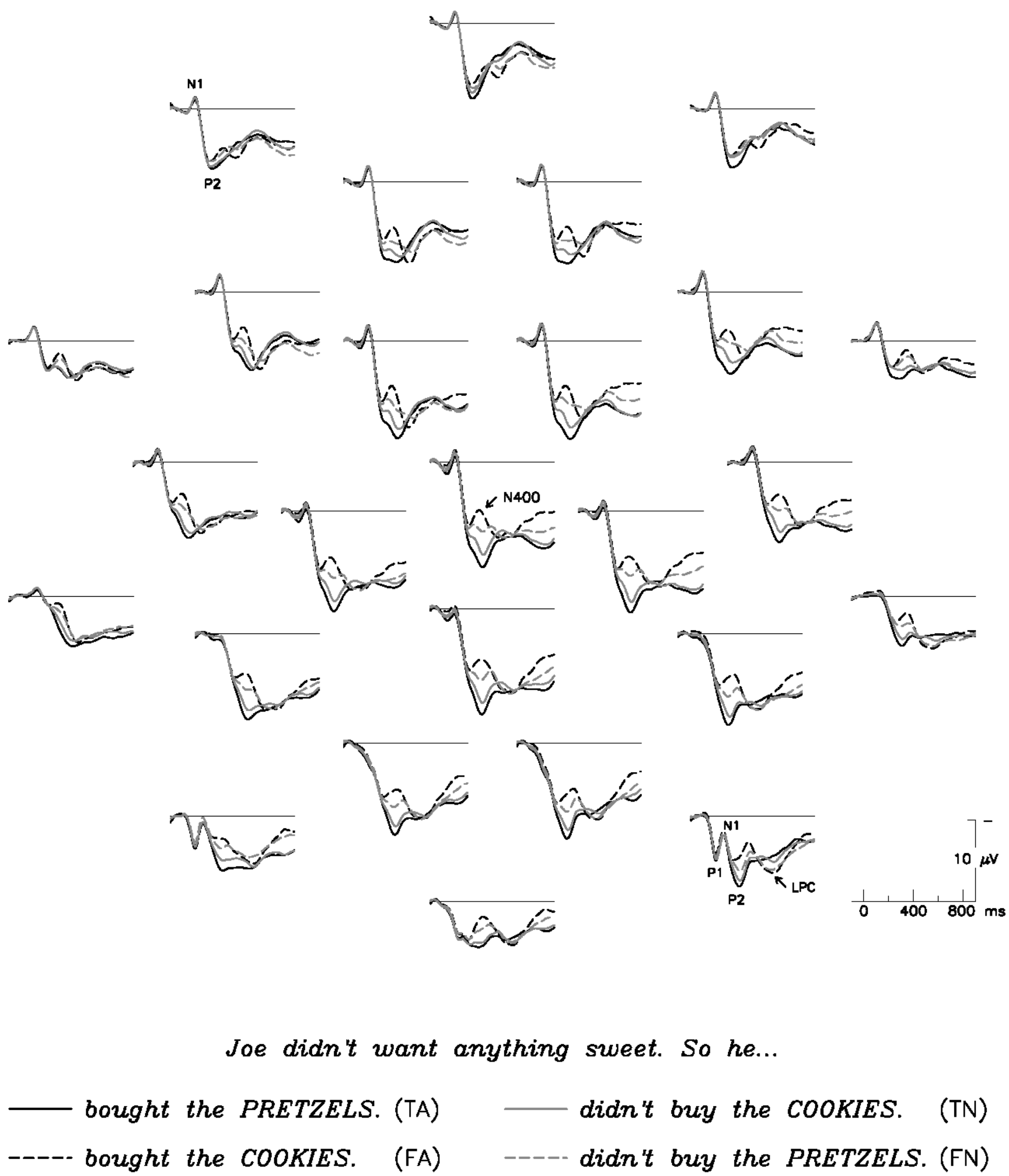

Figure 4-3. Grand average ERPs to sentence-final target words in Experiment 2a. The electrode layout corresponds approximately to the schematic in Figure 3-1. Major ERP components are labeled.

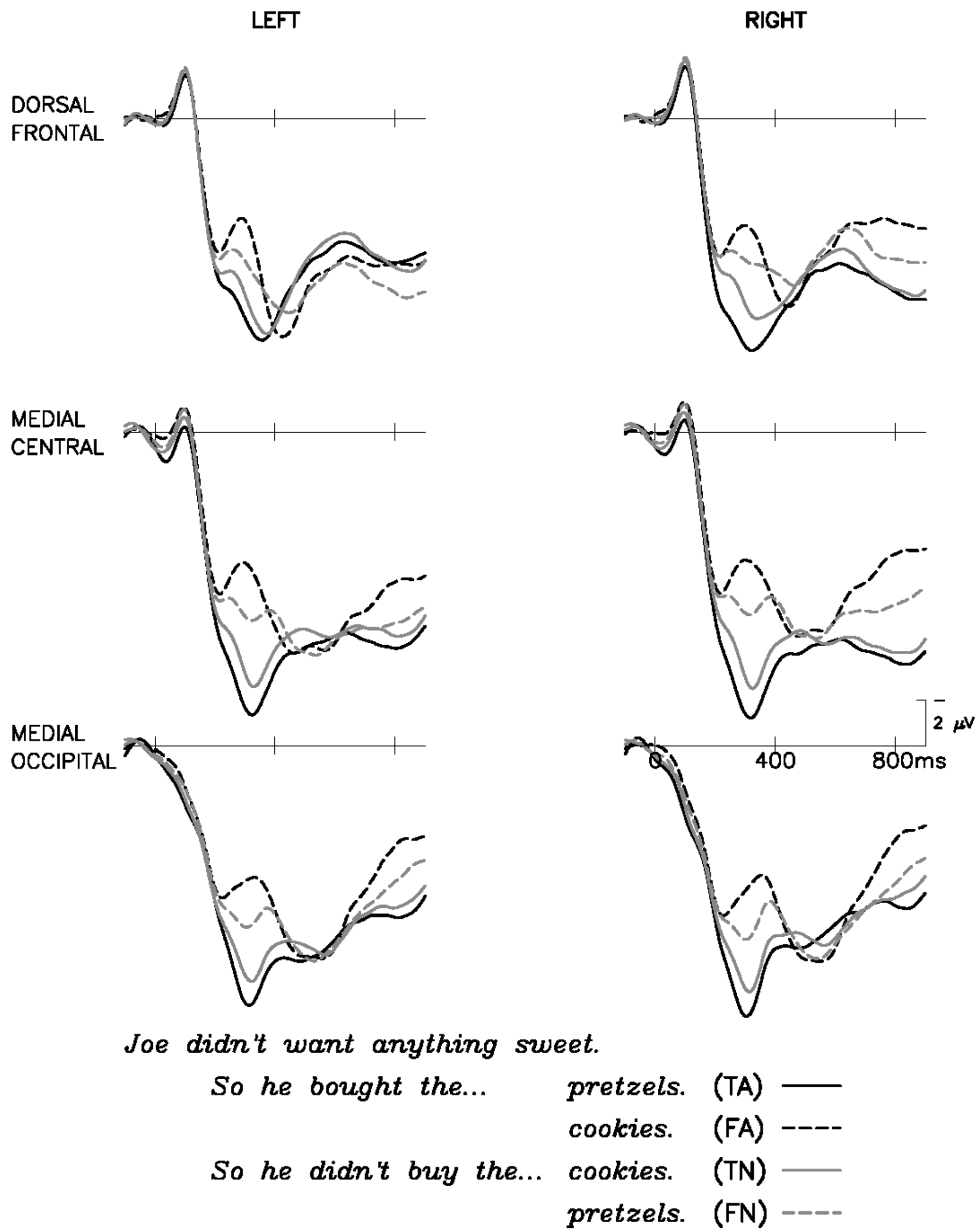

Figure 4-4. ERPs to target words in Experiment 2a. Six selected electrodes are shown.

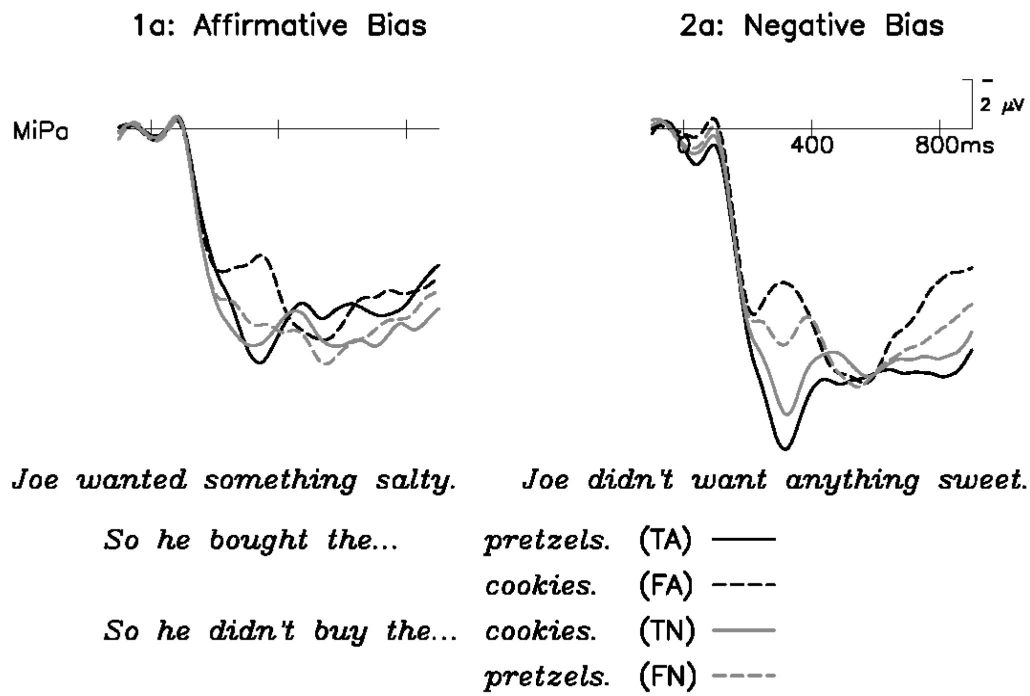

Figure 4-5. ERPs to target sentence endings at MiPa. Plots for Experiments 1a and 2a are presented side by side.

<u>50 – 150 ms</u>

Between 50 and 150 ms after word onset, false endings tended to elicit more negative ERPs than true ones [$F(1, 23) = 3.40$, $p = .078$], but the effect varied in size and reliability across scalp locations [$F(25, 575;\ \varepsilon = .167) = 2.62$, $p = .037$]: It was most prominent at medial [$t(23) = 2.50$, $p = .020$] and posterior [$t(23) = 2.15$, $p = .042$] electrodes. There were no reliable effects of negation in this time-window, neither as a main effect nor in any interactions with truth and electrode [all Fs < 1].

<u>200 – 400 ms</u>

As in Experiment 1a, the N400 was measured between 200 and 400 ms. Figure 4-4 shows that false endings elicited more negative ERPs in this time-window than true endings [$F(1, 23) = 41.28$, $p < .001$]. This truth effect varied in size across the scalp, with a more pronounced negativity at medial [$t(23) = 5.69$, $p < .001$], central [$t(23) = 6.93$, $p < .001$], and posterior [$t(23) = 2.15$, $p = .042$] channels. In addition, it tended to be larger on the right than the left [$t(23) = -1.92$, $p = .067$].

The truth x negation interaction indicated that the truth effect was significantly larger in affirmative sentences than in negative ones [$F(1, 23) = 11.86$, $p = .002$, truth x negation x electrode: $F(25, 575; \varepsilon = .127) = 2.47$, $p = .066$]. TNs were less positive than TAs, and FN showed a trend toward being less negative than FA, although that difference failed to reach significance (*cf*. Table 4-4). Nonetheless, the truth effect was significant for both affirmatives and negatives. This presents an important difference to the N400 results in Experiment 1a, where TN and FN did not differ reliably despite the larger sample size. Also, the truth effect in negatives was more stable across individuals, with a – mostly very small – reversed effect in only six of 24 subjects. Figure 4-5 plots ERPs from the two experiments side by side, illustrating the quantitative differences along with the overall similarity in data pattern. Another difference between Experiments 1a and 2a is the absence of a negation effect [*F*s < 1 for main effect and electrode interaction] in the current paradigm, paralleling the absence of a negation effect on the P2.

Table 4-4. Pairwise comparisons of sentence types for N400 amplitude in Experiment 2a. Raw p values are shown, and differences that are significant after Hochberg (1988) adjustment at the .05 level are marked with an asterisk (*) in the last column.

	F(1,23)	*p*	significance
TA–FA	62.95	<.001	*
TA–FN	23.65	<.001	*
TA–TN	7.37	.012	*
FA–FN	3.25	.084	n.s.
FA–TN	24.20	<.001	*
FN–TN	8.83	.007	*

400 – 600 ms

There was no reliable main effect of truth on the LPC [$F(1, 23) < 1$], but the significant truth x electrode interaction indicated that at some channels false sentence endings elicited more positive ERPs than true endings [$F(25, 575;\ \varepsilon = .172) = 5.91$, $p < .001$]. This positivity appeared at non-central[13] [$t(23) = 2.84$, $p = .009$], mostly posterior [$t(23) = 2.06$, $p = .051$] sites. The absence of an LPC effect at central electrodes may have been due to the large preceding negativity to false targets, effectively "pulling" the ERPs so far negative as to prevent a cross-over in the opposite (positive) direction. In fact, Figure 4-5 shows that the N400 to false endings in the current experiment was followed by a comparable or even more pronounced positive-going deflection (4.06 µV; negative-to-positive-peak at MiPa) than in Experiment 1a (3.42 µV), where the LPC main effect was significant. In that experiment, however, the preceding N400 effect was notably smaller than in the current one (-4.35 µV in 1a *vs*. -6.75 µV in 2a; FA-TA at

[13] The term 'non-central' refers to prefrontal and occipital electrode sites. See Appendix C for a description of the contrasts used in the ERP analyses.

MiPa), which may have facilitated the crossing of the ERP waveforms. As in Experiment 1a, there were no significant effects or interactions involving negation [all *F*s < 1].

<u>600 – 900 ms</u>

After 600 ms, ERPs to false sentence endings were significantly more negative than those to true endings [$F(1,23) = 6.94$, $p = .015$]. This effect was sustained, and it varied in size across the scalp [$F(25, 575; \varepsilon = .133) = 10.11$, $p < .001$], with a more pronounced negativity on the right [$t(23) = -2.69$, $p = .013$], as well as at medial [$t(23) = 3.62$, $p = .001$] and central [$t(23) = 4.80$, $p < .001$] electrodes. Negation had no independent effect on mean amplitudes [main effect: $F(1,23) = 1.11$, p = .304; negation x electrode: $F(25, 575; \varepsilon = .169) = 1.18$, $p = .324$]. There was, however, a trend toward a truth x negation interaction [$F(1, 23) = 3.18$, $p = .088$; truth x negation x electrode: $F(25, 575; \varepsilon = .183) = 1.44$, $p = .221$], as the difference between true and false targets tended to be larger for affirmatives than negatives. Overall, this result pattern differs markedly from that found in Experiment 1a, where the negation effect was significant, but the truth effect was not.

4.1.2.3 Summary of Main Results

Response times to true sentences were shorter than to false ones, although this effect failed to reach significance for negative sentences. N400 amplitude showed a similar pattern with a larger truth effect for affirmatives compared to negatives, but the effect was significant in both sentence modes. A similar ordering of ERP amplitudes to the different sentence types (FA≥FN>TN≥TA) was observed both in a very early time-window (50-150 ms) as well as after 600 ms post target onset, although the interaction between truth and negation was not reliable in these two time-windows. The LPC truth effect was significant only at non-central electrodes, perhaps because of the increase in the amplitude of the preceding N400 effect. As in Experiment 1a, words following a negation marker elicited more negative going ERPs than the same segment in affirmative sentences.

4.1.3 Discussion

One goal of this study was to replicate the findings of Experiment 1a. Like in the earlier experiment, affirmative and negative target sentences were embedded in choice settings that introduced the appropriate endings for both negative and affirmative sentences and provided enough information to correctly predict the correct target word in both types of sentences. N400 amplitude and RTs were therefore expected to show a main effect of truth as evidence that subjects predicted different endings in affirmative and negative sentence contexts. The results of the experiment conformed to this prediction. A main effect of truth was observed for both N400 amplitude and verification times, with true targets producing smaller N400s and shorter RTs than false ones. As in Experiment 1a, both types of dependent measures also showed an interaction between truth and negation, with the truth effect being more pronounced in affirmative than in negative sentences.

Unlike Experiment 1a, the current experiment employed negative bias sentences. That is, the bias sentence gave information about what the character did *not* like or would most probably *not* choose. The correct ending of negatives (which was identical to the FA target) was therefore primed and could be inferred directly from the bias sentence, while the TA (and FN) target received no direct facilitation – which was the opposite situation from the previous ERP experiment. As a result of this stronger facilitation of the correct ending of negative sentences and the lack of priming of the FN target, the truth effect within negatives was expected to be stronger than in Experiment 1a, where it was the FN and not the TN that was related to the bias sentence. Indeed, the N400 difference between TN and FN was statistically significant in the current but not the previous study, despite a smaller sample size. This fact considered by itself could be taken as evidence for the importance of the semantic relationship between the target and words in the bias sentence. If this lexical-semantic relationship was truly the other major determinant of N400 amplitude in addition to truth, we should have observed a larger truth effect for negatives than affirmatives and a smaller N400 to TN than TA. The opposite was the case, however: the truth effect was smaller in negatives, and TN elicited larger N400s than TA. So the TA was more and the TN less primed by the bias sentence than would be expected from the relatedness of bias content and target alone.

The larger than expected facilitation of TA targets is most likely due to the fact that not only are the words or facts explicitly mentioned in a text, but also that the inferences derived from it affect the processing of upcoming information. The result of such an inferential process becomes part of the discourse representation (Graesser, Millis, & Zwaan, 1997) and can therefore prime other concepts or affect predictions about following words or facts. In the binary scenarios of this experiment, the information about what the character in the story would probably not choose allowed deducing what the character was more likely to choose instead, and this inferred concept was integrated into the situation model. The TA ending was thus already activated, and a subject could easily predict the correct ending of an affirmative sentence. The strong truth effect in affirmatives suggests that participants routinely made this inference and activated the corresponding concept. The results of this experiment thus provide some support for the claim that inferences made from the bias sentence have a large impact on the accessibility of concepts in at least the following sentence, if not longer.

Inferences alone, however, cannot explain why negative sentences not only failed to show larger, but in fact produced smaller truth effects than affirmatives. The facilitation that the TN received from the bias sentence and the ensuing negative inference must have been diminished. The most plausible account is that the information was backgrounded because it was negated. A number of studies have demonstrated that negation can suppress or direct attention away from concepts within its scope (e.g., Kaup, 2001; Kaup, Lüdtke, & Zwaan, 2006; Lea & Mulligan, 2002; MacDonald & Just, 1989). This effect may not be obligatory, but it appears to be the default mechanism that is employed unless contextual cues favor and/or actively support the retention of the information (Giora, 2006). In the current experiment, the redirection of attention was facilitated by the presence of an affirmative alternative which could be focused instead. Since affirmative sentences are more frequent than negatives in discourse and writing (Tottie, 1991), an affirmative target sentence may naturally have appeared more likely to participants. A primary focus on the affirmative option at the expense of the negative one may therefore have been most appropriate given a subject's limited processing resources or working memory capacity. Overall, the present results suggest that the negative information contained in or derived from the bias sentence was suppressed.

As in Experiment 1a, verification times followed a pattern that was similar to the N400 results, with the exception that RTs showed an additional main effect of negation. Apart from this, smaller N400 amplitude mapped onto faster RTs. So participants verified true sentences faster than false ones, but this truth effect was smaller in negatives than in affirmatives. In fact, the effect did not reach significance for negatives. This is somewhat surprising as the experiment was designed to promote the advantage of TN over FN, and the N400 data did show a reliable effect. It is possible that the reduced sample size (with respect to Experiment 1a) was responsible for this failure to detect a significant difference. Participants in the ERP experiments were not instructed to respond as quickly as possible, which may have led to high trial-to-trial variability and further reduced power. Between subject variability, however, is probably not the cause, as the percentage of subjects with the majority pattern (FN>TN) was higher in the current than in the preceding study, which did find a significant effect. These differences in significance notwithstanding, the RT data largely conform to the N400 data pattern, as expected.

The ERP also showed patterns that were similar to the N400 in two additional time-windows. Between 50 and 150 ms as well as after 600 ms post stimulus onset, false sentence endings elicited more negative-going ERPs than true ones. Visual inspection suggested that the effects might be larger in affirmatives, but this was not supported by inferential statistics. Interestingly, the early effect was not present in Experiment 1a, and the later slow wave followed a different pattern with relatively more negative ERPs to affirmative targets. At this point, however, we cannot offer an interpretation for these findings. The functional interpretation of these effects, the differences between Experiments 1a and 2a, and the question of whether the resemblances to the N400 pattern are meaningful or merely coincidental are not clear.

In Experiment 1a, targets in negative sentences elicited larger P2s than affirmative sentence targets, but in the current study no P2 effects were evident. We suggested in the discussion of Experiment 1a (cf. section 3.1.4) that the P2 effect may have reflected a competition between more alternatives in negative sentences, as subjects were not able to make equally strong predictions in these sentences. The absence of such an effect here may indicate that using a negative bias sentence facilitated the prediction of the negative sentence ending, thereby reducing the number of target candidates. This interpretation would certainly be consistent with the increased truth effect for negatives in the current study compared to Experiment 1a.

The LPC data also differed somewhat from the previous results. In the current study, the truth effect on the LPC, a larger positivity to false targets, was present only at peripheral electrode locations, while it was more broadly distributed in Experiment 1a. The reason for this divergence may lie in the larger N400 effect in the current experiment. The N400 directly precedes or even overlaps the LPC, and it is largest over medial-central sites. Since the N400 truth effect is a negativity, it may have counteracted the subsequent positivity. In fact, the drop from the N400 to the LPC peak for FA was larger in the current than in the prior experiment, yet the waveform of the FA did not cross that of the TA to produce a measurable LPC difference. Thus, while a positive going component may have been present, it may have been hidden by the large preceding negativity.

Finally, verbs in negative sentences elicited more negative going ERPs than the same words in affirmative contexts. The same result was found in Experiment 1a, and the same interpretation should apply. The ERP difference indicates that subjects have registered the negation marker. The distribution of the effect further suggests that it may index a working memory-supported retrieval process, which presumably is more effortful in negative sentences, as the negative ending is less accessible. The most prominent effects of Experiment 1a, i.e., the truth effects in verification times and N400 amplitudes as well as the negativity to verbs in negative contexts have thus been replicated.

4.2 Experiment 2b: Whole-Sentence Verification

When using affirmative bias sentences in Experiment Set 1, verification times for negative sentences proved highly sensitive to the way target sentences were presented. TN were verified faster than FN when the target sentences was presented word-by-word (Experiment 1a and 1c), but the opposite pattern was found when it appeared as a whole (Experiment 1b). We attributed the reversed truth effect in whole-sentence presentation to a lack in time and processing resources needed to retrieve the correct negative ending (the negative inference from the bias sentence) before encountering the actual sentence-final word. As the TN ending failed to be pre-activated, the other alternative, corresponding to the TA and FN ending, remained active. As a result the FN was processed faster than the TN.

Experiment 2a provided support for the idea that the negative inference becomes or remains more activated and easier to retrieve if the corresponding negative (and not the affirmative) information is presented explicitly in the bias sentence. The N400 amplitude difference between TN and FN, which was not significant in Experiment 1a, became reliable and larger when negative bias sentences were employed. A similar facilitation of TN compared to FN should be observed in a whole-sentence verification paradigm if the common explanation for N400 and RT data proposed in the discussion of Set 1 holds. So the advantage of FN over TN that was observed in Experiment 1b should be reduced, and perhaps TN might even be verified faster than FN despite whole-sentence presentation.

The purpose of the present experiment was to test this hypothesis. It employed the stimulus material from Experiment 2a in a verification paradigm where the entire target sentence appeared at once. A reduced or reversed RT difference between TN and FN compared to Experiment 1b would provide further evidence in favor of common mechanisms underlying

N400 and verification time. The lack of such a change would suggest that the difference in bias sentence structure does not affect RTs, and this might be hard to accommodate by the account proposed in section 3.4, which assumed all factors affecting the accessibility of concepts to have similar effects on N400 amplitude and verification times.

4.2.1 Method

4.2.1.1 Subjects

Sixteen subjects (13 women) with a mean age of 20.2 years (range 18-34 years) participated for academic credit or a cash payment of $7/hour. All were right-handed native speakers of English with normal or corrected to normal vision and no history of neurological disorders.

4.2.1.2 Materials, Procedure, and Data Analysis

The materials were identical to those used in Experiment 2a. Test administration, and stimulus presentation followed the same procedures as Experiment 1b. The analysis of the RTs was based on 92% of the collected data; the remaining 8% were incorrect responses or outliers and therefore excluded.

4.2.2 Results

Subjects achieved mean scores of .186 (*SD* = .089) and .294 (*SD* = .133) on the ART and MRT, respectively. They completed the neutral version of the Stroop in 35.9 s (*SD* = 4.0 s), on average, and the interference version took about 62% longer with a mean time of 58.1 s (*SD* = 10.8 s). Overall, these results were similar to those found in the previous experiments.

<u>Accuracy</u>

Overall, subjects verified 94% of stories correctly. Accuracy rates by sentence type are presented in the right panel of Figure 4-6. Negative sentences led to significantly higher error rates than affirmative ones [Wald $z = -2.12$, $p = .034$]. The size of this negation effect was not affected by the truth of a sentence [Wald $z = -0.25$, $p = .802$], and truth did not produce a reliable main effect [Wald $z = 1.18$, $p = .238$], either. There was also no linear change in accuracy over the course of the experiment [Wald $z = 0.57$, $p = .570$].

<u>Response Times</u>

RTs decreased over the course of the experiment [$F(1, 1759) = 119.95$, $p < .001$], and they increased with sentence length [$F(1, 1759) = 453.02$, $p < .001$]. In addition, they varied systematically across the sentence types. The left panel of Figure 4-6 as well as Table 4-5 present mean RTs by sentence type in milliseconds and as log-transformed values, respectively. Both show that affirmative sentences were verified faster than negative ones [$F(1, 1759) = 146.99$, $p < .001$], and that the direction of the truth difference differed between affirmatives and negatives [truth x negation: $F(1, 1759) = 65.33$, $p < .001$] despite an overall significant truth main effect [$F(1, 1759) = 26.13$, $p < .001$]. That is, TA were verified significantly faster than FA, while TN appeared to lead to longer RTs than FN, but this latter difference was not reliable (*cf*. Table 4-6). Thus, the overall data pattern with reversed truth effects between affirmative and negative sentences was comparable to the results of Experiment 1b with, but the TN-FN difference was less clear here (following negative bias) than in the study with affirmative bias.

Table 4-5. Response times for Experiment 2b. The first row shows averages and standard deviations (in parantheses) based on all individual data points, which were the used in the mixed-model analysis. For comparison purposes, the second row presents the same statistics for traditional by-subject averages, the basis for Figure 4-6.

	TA	FA	TN	FN
Prior Averaging				
None	3.077 (0.151)	3.139 (0.159)	3.222 (0.158)	3.203 (0.164)
By-Subject	3.077 (0.097)	3.140 (0.109)	3.224 (0.114)	3.205 (0.118)

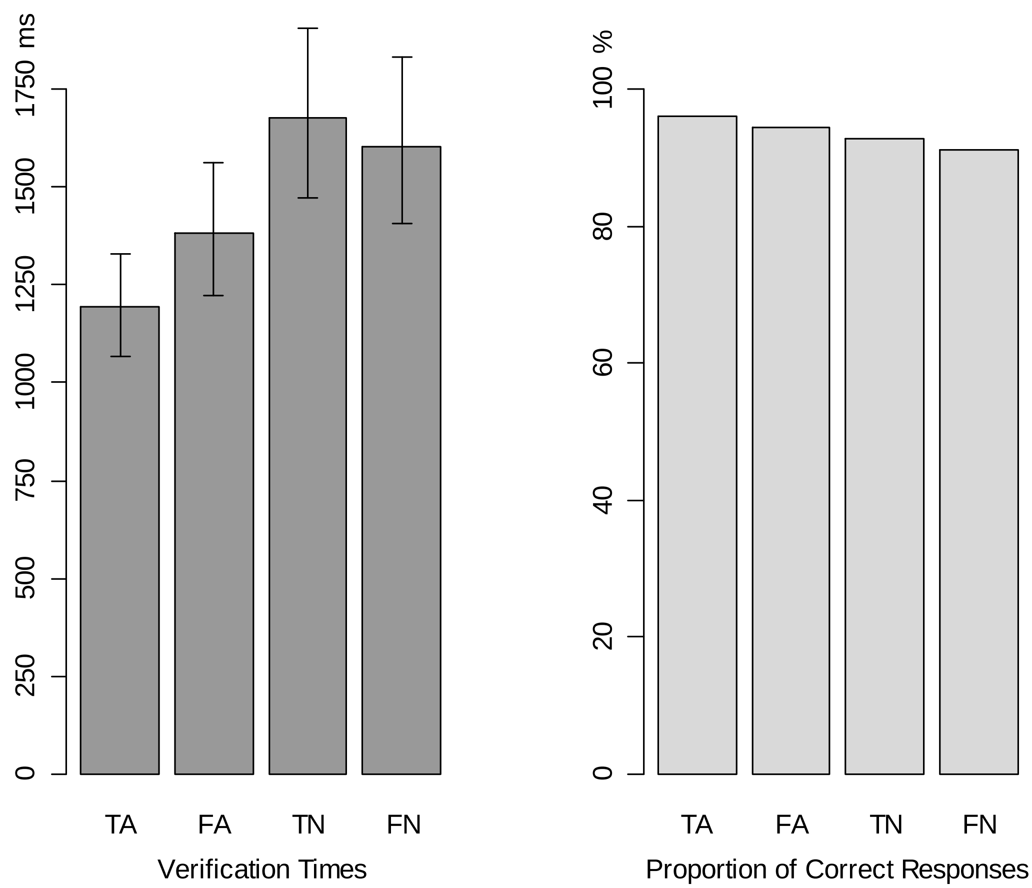

Figure 4-6. Verification times and accuracy in Experiment 2b. The left panel shows mean response times with 95% confidence intervals. Means and standard errors were computed on by-subject averages of log-transformed data. Back-transformed values are shown. The right panel shows the proportion of correct responses computed over all subjects and items.

Table 4-6. Pairwise comparisons of RTs in Experiment 2b. Raw p values are shown, and the right-most column indicates whether the comparison is significant at the .05 level after Hochberg (1988) adjustment, with a star (*) indicating significance.

	z	*p*	significance
TA–FA	-9.31	<.001	*
TA–FN	-12.50	<.001	*
TA–TN	-14.50	<.001	*
FA–FN	-4.22	<.001	*
FA–TN	-6.21	<.001	*
FN–TN	-2.19	.126	n.s.

4.2.3 Discussion

The goal of the present study was to test whether negative bias sentences would have the same effects on RTs a whole-sentence verification task as on N400 amplitude in a word-by-word presentation paradigm. It therefore employed the same stories that were used in Experiment 2a in a whole-sentence verification paradigm.

Using this paradigm, but affirmative bias sentences, Experiment 1b found that affirmative and negative sentences showed opposite truth effects: while TA were verified faster than FA, TN led to longer RTs than FN. The reversed truth effect in negatives was attributed to subjects' inability to predict the correct negative ending before encountering the actual target word in negative sentences, due to the suppression of negative information inferred from the bias sentence and a lack of time and processing capacity to re-activate it. The suppression of this negative inference was probably aided by the fact that it was not very prominent, as it was not directly referred to in the bias sentence, but could only be deduced logically.

In order to increase the prominence of negative information, the present experiment employed negative bias sentences that explicitly mentioned information pertaining to the TN ending. Experiment 2a showed that the use of negative bias sentences could indeed facilitate the maintenance or retrieval of a related negative inference, leading to a processing advantage of TN over FN. In the present whole-sentence verification experiment, this facilitation of TN relative to FN could have translated into a reduction of the reversed truth effect observed in Experiment 1b, or it could even have led to a 'normal' truth effect, with faster RTs to TN than FN. The former was the case: RTs to TN were still numerically longer than those to FN, but the difference between TN and FN was smaller than in Experiment 1b (71 ms vs. 121 ms, respectively) and not reliable.

The absence of a more extreme change in effects (faster RTs to TN than FN) is not surprising. The N400 amplitude pattern in Experiment 2a did not differ dramatically from that observed in Experiment 1a, either; the truth effect in negatives was now larger and significant, but it was still smaller than the truth effect in affirmatives. So the changes due to the use of negative bias sentences were relatively modest in both paradigms. These results support the common account of N400 and RT patterns proposed earlier.

4.3 Experiment 2c: Word-by-Word Verification

Experiments 2a and 2b showed that participants were more likely to keep negative information active or to retrieve it when the information was explicitly referred to and not merely deducible from the discourse as in Experiments 1a and 1b. The processing of TN was facilitated relative to FN, so that the difference between TN and FN became more similar to that between TA and FA. In Experiment 1c, a word-by word verification paradigm with affirmative bias sentences produced truth effects in negatives and affirmatives that did not differ significantly. That is, whether information was directly referred to in the discourse (affirmative) or whether it had to be inferred (negative) did not make a difference. Using negative bias sentences in the same word-by-word verification paradigm, we thus expect the same results. The TN ending will be primed directly, while the TA outcome needs to be deduced, but the extent to each is facilitated in the appropriate target sentence context may not differ. The present study should therefore replicate Experiment 1c, with shorter verification times for true compared to false sentences and no difference in the size of this effect between affirmatives and negatives, as well as overall longer RTs to negative relative to affirmative sentences.

4.3.1 Method

4.3.1.1 Subjects

Sixteen subjects (15 women) with a mean age of 20.0 years (range 18-23 years) participated for academic credit or a cash payment of $7/hour. All were right-handed native speakers of English with normal or corrected to normal vision and no history of neurological disorders.

4.3.1.2 Materials, Procedure, and Data Analysis

The scenarios used in Experiment 2a and 2b served as stimulus materials. Test materials and administration, stimulus presentation and data analysis followed the procedures outlined for Experiment 1c. The analysis of RTs was based on 92% of trials; the remaining trials were lost due to removal of incorrect responses and outliers.

4.3.2 Results

Print exposure scores and Stroop times in this sample were comparable to those observed in the previous five experiments. Subjects achieved mean scores of .208 (*SD* = .107) on the ART and .264 (*SD* = .137) on the MRT. They completed the no-interference part of the Stroop in 33.7 s (*SD* = 5.7 s), on average, and the interference version in 54.4 s (*SD* = 9.8 s), i.e. about 62% more time.

<u>Accuracy</u>

Approximately 94% of scenarios were verified correctly, and there was a non-significant trend for accuracy to increase from the beginning to the end of the experiment [Wald z = 1.72, p = .085]. As the right panel of Figure 4-7 shows, affirmative sentences led to more correct responses than negative ones [Wald z = -3.03, p = .002]. The apparent tendency toward more correct verification of true scenarios compared to false ones was not reliable, however [Wald z = 1.32, p = .188]. There was also no difference between the negation effects in true and false stories [Wald z = -0.08, p = .938].

<u>Response Times</u>

Mean RTs in milliseconds are presented in the left panel of Figure 4-7, and Table 4-7 shows descriptive statistics for log-transformed data. The data pattern and statistical results were very similar to those observed for Experiment 1c, which also employed word-by-word verification, but following affirmative bias sentences. RTs decreased slightly, but reliably over the course of the experiment [$F(1, 1746) = 82.60$, $p < .001$]. Negative sentences took longer to verify than affirmative ones [$F(1, 1746) = 15.84$, $p < .001$], and false ones led to longer RTs than true sentences [$F(1, 1746) = 52.29$, $p < .001$]. These two effects were independent

[$F(1, 1746) = 1.95$, $p = .163$], indicating that the truth effect was of similar size and direction for affirmatives and negatives. That is, TA were verified faster than FA, and TN had a comparable RT advantage over FN (see Table 4-8 for multiple comparisons). The data pattern was relatively stable across individuals, with only three of sixteen subjects showing a reversed truth effect for negatives.

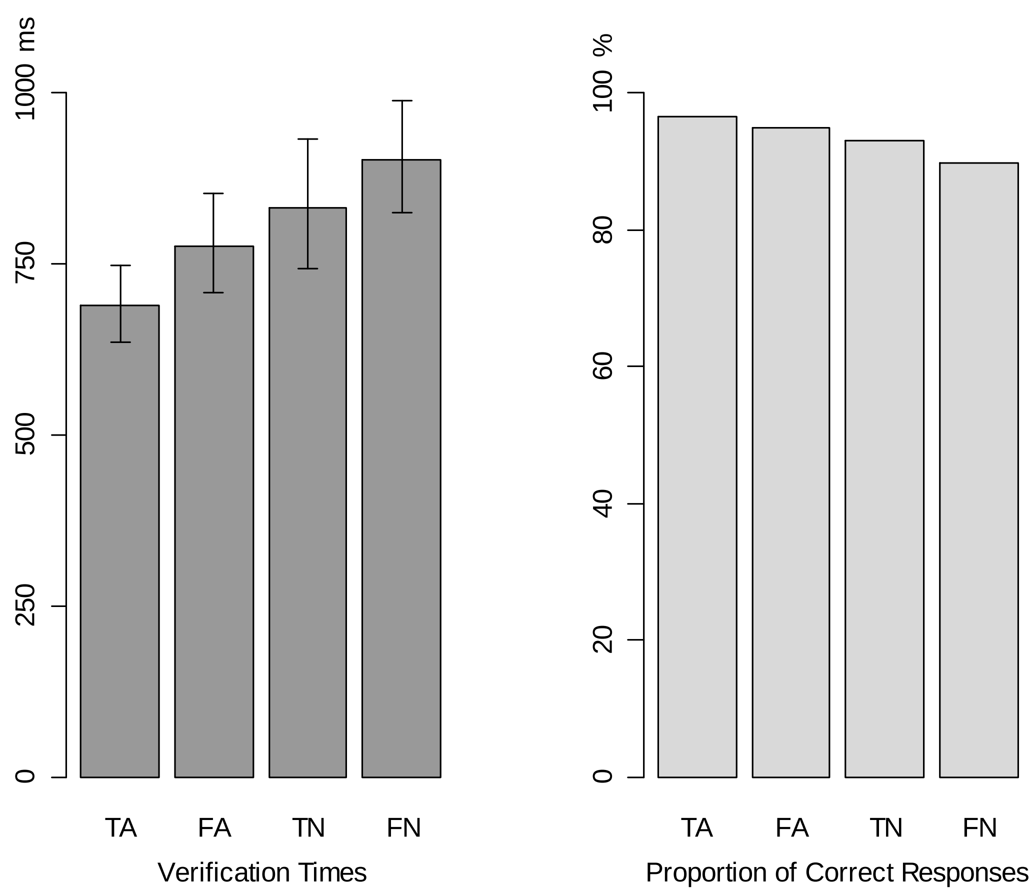

Figure 4-7. Verification times and accuracy in Experiment 2c. The left panel shows mean response times with 95% confidence intervals. Means and standard errors were computed on by-subject averages of log-transformed data. Back-transformed values are shown. The right panel shows the proportion of correct responses computed over all subjects and items.

Table 4-7. Response times for Experiment 2c. The first row shows averages and standard deviations (in parantheses) based on all individual data points, which were the used in the mixed-model analysis. For comparison purposes, the second row presents the same statistics for traditional by-subject averages, the basis for Figure 4-7.

	TA	FA	TN	FN
Prior Averaging				
None	2.839 (0.140)	2.889 (0.131)	2.923 (0.174)	2.956 (0.151)
By-Subject	2.838 (0.072)	2.890 (0.082)	2.921 (0.101)	2.956 (0.081)

Table 4-8. Multiple comparisons of RTs in Experiment 2c. Raw p values are shown, and the right-most column indicates whether the comparison is significant at the .05 level after Hochberg (1988) adjustment, with a star (*) indicating significance.

	z	*p*	significance
TA–FA	-6.15	<.001	*
TA–FN	-13.85	<.001	*
TA–TN	-9.89	<.001	*
FA–FN	-7.76	<.001	*
FA–TN	-3.74	<.001	*
FN–TN	4.06	<.001	*

4.3.3 Discussion

As predicted, participants verified true sentences faster than false ones, and the difference was similar for affirmatives and negatives. As in the previous study using affirmative bias sentences, it did not matter how directly the target was related to the bias sentence. Apparently, under these presentation parameters, participants could predict the correct sentence ending, whether it followed directly from the information in the bias sentence or had to be inferred logically. These results, like those of Experiment 1c, also demonstrate that the size of the inhibitory effect of negation is variable. In fact, neither verification experiment using word by word presentation showed evidence for suppression in the form of a reduced truth effect in negatives. Given a task for which the retention of negative information is useful and that puts little strain on processing or working memory capacity, it seems that negated concepts can remain as accessible as non-negated ones.

4.4 Summary and Discussion of Experiment Set 2

The goal of this 2nd series of experiments was to replicate the negation effects observed in Set 1 and to assess the impact of using negative bias sentences on the strength of these negation effects. Experiment Set 1 showed that negation could change a subject's expectation about upcoming lexical items if the sentences were embedded in contexts that contained enough information to make the continuations predictable in both affirmative and negative sentences. The experimental scenarios presented two alternatives from which a character would choose along with information about the character's preferences. As a result, the reader could anticipate which option the character would select, but he could also infer which option should not be chosen. The extent to which a subject could use the negative information to update expectations while processing the final sentence of the story depended both on subject and on experimental variables. We found evidence for effects of processing strategies and of the timing of the target sentence presentation as it affected how much time and processing resources she could devote to the activation of lexical items prior to their appearance.

Like Set 1, the present series of experiments was based on choice scenarios with two options that allowed for precise predictions in both affirmative and negative sentences. We therefore expected to observe negation-induced changes in what was predicted. The scenarios were employed in the same experimental paradigms as were used in Set 1, so that the result patterns should show similar changes as a function of the specific task demands.

The results of Experiments 2a-c were in line with these predictions. Both N400 and RT data largely resembled the results found in Experiments 1a-c. In the ERP experiment, the truth effects in affirmative and negative sentences were qualitatively similar, with smaller N400 to TA and TN relative to FA and FN, respectively. The word-by-word verification task again yielded equal RT differences between true and false sentences for affirmatives and negatives, while the whole-sentence verification paradigm produced a reversed truth effect in negatives only.

These overall similarities were complemented by some subtle differences presumably due to our use of negative bias sentences. The negative bias sentences may have primed the processing of negation in the target sentence, speeding up the integration of the negation marker and thereby making a quick change in expectation more likely. Furthermore, these sentences stated a character's dislikes and thereby implied what that character what probably not choose, i.e. the concept that should complete a correct negative target sentence. This negative ending was therefore much more prominent, and presumably easier to predict, than in the previous set of experiments. As a result, TN received more facilitation relative to FN than in the affirmative bias contexts. In Experiment 2a, this translated into an increased and now reliable N400 truth effect for negatives. The whole-sentence verification task produced a smaller RT disadvantage for TN compared to FN, and the difference was no longer significant. The result pattern of the word-by-word verification experiment, however, did not change from affirmative to negative bias, as the RT difference between true and false sentences was again similar in affirmatives and negatives. This task appears to be so easy that subjects can correctly anticipate the endings of both affirmative and negative sentences, irrespective of whether the context recently referred to the word, or whether it had to be inferred. Experiments 1c and 2c differed in which of the two endings was more directly primed by the context, but it made no difference to the verification outcome when the test sentence was presented one word at a time.

In the discussion of Experiment Set 1, we proposed an account of the processes that affect the ability of negation to change a subject's expectations about upcoming sentence elements. An assumption in this account was that both N400 amplitude and verification times were affected by manipulations of concept accessibility. Changing the structure of the bias sentence from positive to negative improved the accessibility of the correct negative ending, and both measures reflected this in increased facilitation of TN relative to FN. Furthermore, both changes were of similar magnitude, as the data patterns remained qualitatively the same, but the size and reliability of effects changed. The results from Set 2 were thus consistent with the ideas derived from the earlier experiments: They demonstrated that differences in predictability between affirmative and negative sentences vary with the level of activation of the concept to be predicted, and they showed similar effects on N400 amplitude and RTs.

The proposed account also underscored that the accessibility of a concept does not merely depend on whether it is explicitly mentioned or semantically related to discourse elements. What matters is its relationship to the discourse *representation*, which contains elements that occur explicitly, but also some that are inferred from the text based on world knowledge and rules of mental logic. Looking at the text base alone, one would have expected the correct negative ending to be more activated than the affirmative one in the present set of experiments. In all three experiments, however, the truth effect in affirmatives was at least as strong as that in negatives. So the TA must have received some additional facilitation. The best explanation for this is that subjects inferred the correct affirmative ending from the bias sentence, and the result of the inference became part of subjects' mental representation of the discourse.

In fact, the affirmative inference appears to have been more activated than the negative one, as TAs elicited smaller N400s than TNs, and the truth effect was larger in affirmatives than in negatives in Experiment 2a. Put another way, correct negative endings were less facilitated than expected considering both discourse content and inferences; their activation was thus suppressed, most likely because the information was negative. Inhibition due to negation also played an important role in accounting for the results of Set 1, and a number of studies have reported reduced activation of negated elements, especially when there is an affirmative alternative to which attention can be directed instead (Kaup, 1997; MacDonald & Just, 1989; Mayo et al., 2004). The present results thus provide additional support for focus shifts due to negation, and they support the account, proposed in Chapter 3, of how negation can induce changes in expectations about upcoming information in the same sentence.

CHAPTER 5

GENERAL DISCUSSION

Negation changes the meaning of a sentence. To achieve this, it must somehow affect the representation of the sentence or the representation(s) of the sentence constituents to which it applies. There are different psycholinguistic theories of how negation is represented at the level of meaning, and these theories have been invoked to explain negation effects on overall processing difficulty and the activation and interpretation of concepts in negative sentences. These negation effects have almost always been probed after the end of the sentence, as research has typically focused on the complete representation of a sentence.

One may also wonder, however, to what extent negation affects the comprehension of the sentence before a complete representation has been constructed. Does a negation, for example, change the way subsequent lexical items in the same sentence are processed? Semantic models of sentence verification suggest that negation is not dealt with until the embedded affirmative proposition has been processed (Carpenter & Just, 1975; Clark & Chase, 1972; Trabasso et al., 1971). On this view, negation should not have any effect on the processing of words within the sentence to which the negation applies. Fischler and colleagues (1983) tested this hypothesis by measuring the N400 to sentence-final words in affirmative and negative sentences; they found no effect of negation. A word that elicited a small N400 in an affirmative sentence did the same in the corresponding negative, although it rendered the affirmative true and the negative false. Likewise, the word that rendered the affirmative false and the negative true led to enhanced N400s in both sentences, i.e. despite having opposite effects on the truth of the sentences. As in many picture-sentence verification studies, the truth effects in affirmatives and negatives were reversed. Fischler et al. considered this additional evidence for a delayed processing of negation, *following* the processing of the embedded (negated) proposition.

In this dissertation, however, we have proposed an alternative account of this data pattern. We argue that isolated negative sentences, like those used by Fischler and colleagues, typically deny an assumption that is held to be true by the average comprehender. That is, isolated negative sentences are most appropriate or plausible if the negation applies to something that one usually expects to be the case. At the same time, affirmative sentences are also most plausible if they express something that is thought to be true. Accordingly, the word that best completes an affirmative statement, like *bird* completing the sentence fragment *A robin is a,* would also be a good fit for the corresponding negative sentence. Conversely, an unexpected completion for the affirmative sentence, such as *vehicle*, should be no more (or less) expected in the negative statement. There is no reason to deny it, as nobody would have expected that a robin is a vehicle in any case. Overall, then, we maintain that in Fischler et al.'s study, both affirmative and negative sentences were most plausibly completed by the same words, as a function of stereotypical associations or world knowledge.

For negation effects to be detectable, the plausibility of a continuation should somehow depend on the presence or absence of negation. So an ending that is appropriate in an affirmative sentence should not be appropriate in a negative sentence, and vice versa. Embedding the sentences in a context can accomplish this, as the context can provide information to make different options more or less appropriate depending on the sentence mode. In this dissertation, we therefore used context-embedded affirmative and negative sentences: The context introduces two alternatives between which a character had to choose and provides information about the character's inclinations. The target sentence expresses either which option is chosen or which is not. Given the character's preferences or dislikes, one alternative is a better fit in the affirmative sentence, and the other is a better completion for the negative sentence. So the extent to which a final word is facilitated or expected in a sentence should depend on the presence or absence of negation – if negation is indeed processed as soon as it is encountered and not after the end of the sentence.

Early Negation Effects

There is considerable evidence for incrementality in language processing, that is, for the use of linguistic information, as it becomes available, to form predictions about likely sentence continuations (or completions). A lot of this evidence has come from studies employing the visual-world paradigm, in which participants listen to sentences referring to a visual scene while their eye movements around the scene are monitored. These studies have shown that different linguistic cues, such as verb semantics (Altmann & Kamide, 1999; Kamide, Altmann et al., 2003) and tense (Altmann & Kamide, 2007) as well as active/passive voice or noun case marking (Kamide, Scheepers, & Altmann, 2003) can be used to anticipate upcoming information. In addition, ERP research has demonstrated that people sometimes predict not only general semantic content, but specific words including their phonological and grammatical features (DeLong et al., 2005; Otten, Nieuwland, & Van Berkum, 2007; van Berkum et al., 2005; Wicha et al., 2004).

The goal of this dissertation was to assess whether negation, too, can be an incrementally processed linguistic cue that affects expectations about subsequent lexical items. We used the N400 to sentence-final words as the main dependent variable. Under the null hypothesis, according to which negation is processed only after the sentence-final word, one would not expect to find any effect of negation in target N400 amplitude. That is, the relative N400 amplitude to two words should be unaffected by negation, even though one word renders the affirmative true and the negative false (e.g. *pretzels* after …*salty*), while the other one (*cookies*) has the opposite effect. As a result, the truth effects in affirmatives and negatives should be exact opposites. We predicted, however, that negation would have an effect on the N400 pattern. At the very least, the reversed truth effect in negatives (TN>FN) should be smaller than the regular truth effect in affirmatives (FA>TA), meaning that negation changed expectations only partially. At most, affirmatives and negatives would show equal truth effects, signaling a complete reversal of expectations due to negation.

The N400 pattern we observed in both ERP studies conformed to our hypothesis, and it fell somewhere between the two extremes. In both affirmative and negative sentences, false endings elicited (at least numerically) larger N400s than true endings, but this truth effect was smaller in negative than in affirmative sentences. So negation seems to have affected expectations, although it did not reverse them entirely. In any case, we can conclude that negation, like other linguistic cues, can, at least sometimes, be processed soon after it is encountered and, under the right circumstances, can influence the prediction of upcoming lexical items within the same sentence in which the negation appears.

Our results are thus in conflict with Fischler's (1983) proposal that negation is dealt with only *after* the inner proposition has been processed. As mentioned before, this proposal was directly derived from formal semantic accounts of sentence comprehension and verification, which suggest that negation acts as an embedding proposition, and that processing proceeds from the innermost to the outermost proposition (e.g., Carpenter & Just, 1975). These models have been quite successful at accounting for a vast amount of data on sentence verification and comparison. Recently, however, Kaup and her collaborators have put forward an alternative account of the representation of negation that can explain the same findings (Kaup, 2006; Kaup, Zwaan et al., 2007). This account dispenses with abstract propositional representations and suggests that negation is implicitly encoded in the difference between two mental models or simulations: that of the expected state of affairs and that of the actual state of affairs, which lacks the negated concepts. Importantly, it can not only explain the same array of sentence verification data as the semantic models, but additionally offers an explanation for different findings of pragmatic influences on negation processing (e.g., Glenberg et al., 1999; Lüdtke & Kaup, 2006), which cannot easily be accommodated by the semantic models. Kaup's account does not make predictions about the order in which information is processed or integrated into representations. Like our N400 results, however, it presents a challenge to the propositional analysis of negation.

In addition to these theoretical considerations, our findings also have methodological implications. At a general level, they show that taking pragmatics into account in the design of stimuli or the interpretation of experimental results can make an important difference when studying linguistic phenomena, such as negation, that are strongly context dependent and that have distinct discourse functions. Furthermore, pragmatics should inform definitions of plausibility or expectancy. Certainly, true sentences are usually more expected or more plausible than false ones. This correlation between truth-value and plausibility must be the foundation for claims, based on Fischler's (1983) results, that the N400 is more sensitive to priming than to discourse plausibility (Kolk, Chwilla, van Herten, & Oor, 2003) or sentence congruity and expectancy (Phillips, Kazanina, & Abada, 2005). In fact, Fischler's study only demonstrates a lack of sensitivity to truth. As we have argued above, however, isolated negative sentences should be expected to deny a (presumed) truth and therefore contradict our assumptions about the world – in other words, be false. Since “in real life negatives are false” (Wason, 1971), truth and plausibility or expectancy can be decoupled if negation is involved. So a lack of sensitivity to truth does not imply insensitivity to plausibility. In our stimuli, all target sentences started with adverbs like *therefore*, *hence*, *thus*, or *so* expressing that the target sentence should be logically consistent with the preceding discourse. So these sentences were expected to be true within the discourse context, and we were able to detect a main effect of truth.

When discussing the pragmatic appropriateness of research design, we can of course not overlook one factor that may limit the generalizability of our results: We employed a verification paradigm, which may have encouraged subjects to use particular predictive strategies or to pay more attention to negation than they would in a more natural context. Since Fischler and colleagues (1983) did the same, the comparison remains valid, and we can attribute our finding reliable negation effects to the use of context-embedded stimuli enabling predictions for the ending of negative sentences. Nonetheless, the evidence for early negation effects in discourse comprehension (as opposed to verification) would be more convincing if we could replicate our findings in a more natural comprehension paradigm, where participants are merely instructed to read a story for comprehension without having to make congruency decisions. In addition, one might argue that N400 effects on sentence-final words may reflect sentence ‘wrap-up’ processes that differ from processes that truly occur within the sentence (cf. Osterhout & Holcomb, 1992). A replication of our findings with sentences where the target words are followed by some material (e.g., *He didn’t donate* food/money *to the shelter*) would certainly strengthen the case for intra-sentential negation effects on expectancies.

Inferences and Suppression

As we mentioned above, although true endings elicited (numerically) smaller N400s than false ones in both affirmatives and negatives, the size of this effect differed between the two sentence types, with smaller effects in negatives. When an affirmative bias was used, the truth effect did not reach significance for negatives. In the negative bias condition, it was reliable, but still significantly smaller than in affirmatives. Given that, in principle, the correct ending was equally predictable in both sentence types, these differences implicate some factors other than truth, congruency, or plausibility.

One factor that might help to explain the smaller difference between true and false negatives compared to true and false affirmatives might be the relationship between the target word and the content of the bias sentence. In Fischler et al.'s (1983) experiment, the (categorical) relationship between the subject noun (e.g., robin) and the target noun (e.g., bird) determined the N400 pattern entirely. The equivalent to Fischler's subject noun in our studies would be the word in the bias sentence that hinted at the preferred choice (e.g., salty), which could prime the corresponding target word (pretzels). A combination of relatedness and truth might indeed explain the N400 pattern in Experiment 1a, where an affirmative bias sentence was used. In this case, the TA was true and related, while the FA was false and unrelated, leading to a large N400 difference between the two affirmative endings. For the negatives, a smaller difference would be expected as FNs were false, but related and TNs were true, but unrelated; so each negative ending would receive some facilitation due to one of these two factors. If the effect of truth was stronger than that of relatedness, then FNs should elicit slightly larger N400s than TNs, as observed in our experiment.

Relatedness, however, can hardly explain the correlation between N400 patterns and bias sentence processing times that we observed in Experiment 1a. Possibly, one might have expected that those participants who pay more attention to the bias sentence and therefore spend more time processing it would show stronger priming from the bias sentence to the target word. In this case, the relatedness effect should be stronger relative to the truth effect in these participants, and they should show a larger N400 to TNs compared to FNs, i.e., a weaker or reversed truth effect in negatives. The analysis of subject group differences, however, revealed the opposite pattern: It was the participants that showed stronger truth effects in negatives (larger N400s to FN compared to TN) that tended to take more time to read and process the bias sentence. We took this to suggest that the additional bias processing time might have been related to the encoding of an inference that facilitated the correct prediction of the TN ending: As the bias sentence hinted at what the character was likely to choose – the TA ending – one therefore could also infer what she would most likely not select – the TN target.

Inferences are thought to be represented along with textual information at the highest level of discourse representation, the situation model (or mental model), which is conceived of as a mental representation of the situation described in a discourse or narrative, including the setting, characters, action, motivations, and goals (Graesser et al., 1997; Zwaan, 2004; Zwaan & Radvansky, 1998). The inferred information is an integral part of the representation, and under certain circumstances it can be as active as information that was explicitly mentioned (cf. Keefe & McDaniel, 1993). Psycholinguistic research has mostly dealt with inferences based on the interaction between textual information and world knowledge (such as the inference that a vase broke after having read that it was thrown against the wall), and aimed at determining exactly what kinds of inferences readers routinely draw (e.g., Graesser, Singer, & Trabasso, 1994; McKoon & Ratcliff, 1992).

The inferences that could be drawn from the bias sentences in our experimental materials, however, were not knowledge-based elaborations. Instead, they were inferences based on logical relationships: Given the premises that Joe will choose either cookies or pretzels and that he will probably choose the pretzels (something salty), one can infer by not-both-elimination that Joe will not pick the cookies. Readers appear to routinely make these kinds of logical inferences (Lea, 1995; Lea & Mulligan, 2002), so it is very likely that our participants did so as well. If the inference was made by *all* participants, however, the actual drawing of the inference per se cannot explain the group differences in negation-related truth effects in Experiment 1a.

Instead, we propose that the groups did not differ in how likely they were to make the inference but rather in the extent to which once drawn the inferred information was kept active in working memory. The outcome of a not-both-elimination inference is negative information; it expresses a non-event, such as what the character will *not* pick. Negative information, however, tends to become deactivated, as the focus of attention is often directed away from the negated information (De Mey, 1971; MacDonald & Just, 1989). This seems to be especially likely when a non-negated alternative is available in the context (cf. section 2.2.2.3), which is the case in our experiment as the alternative that would likely be selected. However, negation-induced suppression is not obligatory; it may depend on the comprehender's goals and strategies (Giora, 2006, 2007; Giora et al., 2007). In Experiment 1a, it may have been beneficial to not (completely) suppress the negative inference, as it was useful in anticipating the correct ending of negative sentences, which in turn might have facilitated the speed and accurate of the verification. We therefore suggested that the larger subject group, who took more time to process the bias sentence, made an effort to keep the negative inference active, as reflected in the additional processing time. As a result, these participants were able to predict both TA and TN correctly and showed similar truth effects in both affirmatives and negatives. By contrast, the group that we propose inhibited the negative inference showed a reversed truth effect in negatives, presumably because the information necessary to update their expectations was not available.

Experiment 2a provided additional support for this account. It employed negative bias sentences, which changed the relationship between truth, negation, and relatedness, as well as the type of inference the bias sentence afforded. TA were now true and unrelated and FA were false and related, while TN were both true and related and FN were both false and unrelated. Considering only truth and relatedness, one would therefore have expected to find a larger difference between true and false endings in negative than in affirmative sentences. Yet, the N400 results showed the opposite pattern: While the truth effect was significant in both sentence types, it was larger in affirmatives. This, however, is exactly the pattern one would predict if logical inferences and the suppression of negative information are taken into account. The logical inference in this case was that Joe would choose pretzels, given that his choice was between cookies and pretzels and he did not want anything sweet (i.e., not the cookies). The result of this inference (pretzels) became activated and could therefore facilitate the processing of the TA ending. The information related to the TN, however, was negative itself (not anything sweet) as was the direct inference from it (not cookies). Therefore, it was subject to at least partial suppression, with more attention focused on the affirmative alternative, the result of logical inference. So the TA received additional priming and the TN less facilitation than would be expected from its semantic relationship to the bias sentence. As a result, the truth effect on negatives in affirmative sentences was enhanced and that in negative sentences was reduced, leading to a pattern similar to that observed in the affirmative bias context. Unlike in the affirmative bias context, however, the truth effect in negative sentences was in this case reliable for the whole sample. This may have been due to better retention (less suppression) of the negative information, as it was directly mentioned in the bias sentence and not merely inferred, and therefore more prominent.

Verification Times and Task Effects

So far, our discussion has focused exclusively on the N400 patterns observed in the two ERP experiments. Yet, in the same experiments, we also recorded verification times and found the patterns to be strongly correlated with the N400 patterns. Like the N400, RTs showed facilitation of true sentences relative to false sentences regardless of contextual bias, albeit with a smaller truth effect for negatives compared to affirmatives. In addition to this overall resemblance, we observed in the affirmative bias experiment that the correlation also held on a subject group basis: The participants with significantly larger N400s to FN than to TN showed a similar RT effect, and the participants who presented with a reversed truth effect in negatives for the N400, did so for RTs as well. It thus appears quite likely that the variations in the N400 and RT truth effects for negatives (as for affirmatives) are modulated by the same underlying mechanism. Keeping with the interpretation of the N400 results, we suggest that both N400 and verification times vary with the degree to which expectations about the target word and the actual target stimulus match. On this proposal, the direction and size of the RT and N400 truth effects in negative sentences depend on the extent to which participants anticipated (i.e., predicted) the TN ending.

The truth effect in affirmative sentences was quite consistent in both N400 and RTs across all six experiments, so the correct ending for affirmatives seems to have been predicted reliably. This was probably due to two facts: Given the suppressive effect of negation, participants were more likely to focus attention on the affirmative inference (the TA ending), and this information was therefore presumably most active in working memory when they started reading the target sentence. In addition, affirmative sentences are unmarked and generally much more frequent than negatives (Tottie, 1991), so the default prediction for the target sentence ending before encountering any negation marker would be the TA target. Assuming such a default preference for the TA prediction, expectations would have to be changed when the sentence turns out to be negative instead.

The fact that the two ways of presenting the target sentence, word-by-word vs. whole-sentence, produced opposite RT patterns for negative sentences suggests that the negation-induced expectation change was only possible when a participant had sufficient time and processing capacity to do so. Word-by-word presentation yielded faster RTs to TNs, while FNs were verified faster when the target sentences were presented in their entirety. Since the same stimulus material was used under both presentation regimes, the differences must have been due to the differences in timing and associated task demands. In word-by-word presentation, participants received the information gradually, at a rather slow pace compared to natural reading. Typically, 1500 ms passed between the onset of the negative inflected auxiliary (*didn't*) and the onset of the target word, giving participants sufficient time to retrieve the backgrounded negative information and to use it to pre-activate the correct ending. This was almost as much time as participants in the whole-sentence verification studies took to read *and* verify negative sentences (1542 ms and 1632 ms on average in Experiments 1b and 2b, respectively). Under the assumption that a significant part of the verification time was due to decision making[14], the participants in the whole-sentence paradigm must have read the sentences much more quickly. As a result, there was less time for the negation effect to unfold, and participants presumably had less processing resources available for the retrieval of the correct negative ending. Relatively early negation effects on expectations therefore appear to be limited to situations where a reader (or listener) has sufficient time and processing capacity to effectively use the information provided by a negation marker.

One might argue that the reading of whole sentences is a more natural process, and that the outcomes of the whole-sentence verification paradigms thus better reflect negation processing under normal circumstances. However, in our whole-sentence verification studies, participants were encouraged to respond as quickly as possible, which likely resulted in faster than normal reading: Negative sentences were read and verified in about 1600 ms, which is barely more than the time it should typically take to only *read* them (1300-1600 ms), given an average length of 6.5 words and assuming an average reading time of 200 to 250 ms per word (cf. Rayner & Sereno, 1994). So the pattern found in this whole-sentence verification paradigm may be representative of speeded reading, but not necessarily of natural language comprehension. The question of how (fast) negation is processed under normal conditions can only be answered definitively if either words are presented visually at rates near the natural reading speed (e.g., using a constant SOA of 300 ms or a word-length adjusted rate) or if spoken language stimuli are employed.

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[14] In the word-by-word verification Experiments 1c and 2c, subjects read almost the entire sentence before having to make a verification decision. They still took on average 858 ms or 870 ms, respectively, to verify negative sentences.

Conclusions

Our results are clear: The processing of negation is not necessarily delayed until the end of a sentence or complete processing of an embedded proposition. Instead, a negation marker seems to act as a linguistic cue that can be used by readers to anticipate how the sentence in which it occurs will continue. The use of isolated sentences referring to world knowledge, however, makes the detection of such effects difficult, if not impossible, as decontextualized negative sentences are expected to deny the very concepts (and associated lexical items) that isolated affirmative sentences are expected to affirm. By contrast, a discourse context can make different continuations plausible for affirmative and negative sentences, and as a result, increase the likelihood of detecting negation effects on continuation predictions. A negation-induced prediction change becomes less likely, however, when the most plausible continuation for the negative sentence is itself a negated concept, because negated information becomes suppressed or backgrounded and thereby less accessible. In this case, the expectation change due to negation is likely only to the extent that the sentence is read at a relatively slow rate and the reader is not distracted by other tasks. In sum, negation can have (almost) immediate effects on sentence processing when used in an appropriate context.

APPENDIX A:

EXPERIMENTAL STORIES

The following is a list of the stimuli used in the experiments. For each story, the introduction (I), affirmative (aB) and negative Bias (nB) sentences, as well as the Target sentences (T) are shown. Experiment Set 1 used the affirmative bias sentences, and Experiment Set 2 used the negative bias sentences.

(1)

I: Peter found a fly in his chili and immediately complained to the cashier at Wendy's. As compensation he was offered another meal or a refund of his money.

aB: Peter would rather get [something to eat/his money back].

nB: Peter didn't want [to eat anymore/his money back].

T: So he [accepted/didn't accept] the [meal/refund].

(2)

I: The admissions officer at Castle College had to decide which of two applicants she would admit. One applicant was a successful swimmer, the other an accomplished pianist.

aB: Castle College valued [athletics/arts] more highly.

nB: Castle College didn't value [athletics/arts] much at all.

T: Thus the officer [admitted/didn't admit] the [swimmer/pianist].

(3)

I: Sheriff Cooper spotted a priest and a clown brawling in front of the casino. After Cooper had separated them, each man accused the other of picking the fight.

aB: The [cleric/buffoon] had caused trouble before.

nB: The [cleric/buffoon] had never caused any trouble.

T: Therefore the sheriff [arrested/didn't arrest] the [priest/clown].

(4)

I: Jeremy’s parents were coming to visit, and they’d only given him 15 minutes notice. Should he clean the shower or the fridge?

aB: He knew his mother was obsessed with [bathroom/kitchen] hygiene.

nB: He knew his mother didn't care that much about [bathroom/kitchen] hygiene.

T: Therefore he [cleaned/didn't clean] the [shower/fridge].

(5)
I: Mary's alma mater was raising money to build a new library and a new football stadium. Mary couldn't afford to give money to both causes.
aB: She thought [books/sports] were more important.
nB: She thought [books/sports] were not that important.
T: Hence she [donated/didn't donate] towards the [library/stadium].

(6)
I: Brad’s cat threw up on his homework. He wasn’t sure whom to notify, the professor or the TA.
aB: He felt more comfortable contacting [a younger/an older] person.
nB: He didn't feel comfortable contacting [a younger/an older] person.
T: So he [emailed/didn't email] the [TA/professor].

(7)
I: A notorious drug trafficker was arrested in Miami. Both France and China asked for his extradition.
aB: The US felt more obliged to the [European Union/Asian country].
nB: The US didn't feel any obligation toward the [European Union/Asian country].
T: Therefore they [extradited/didn't extradite] the criminal to [France/China].

(8)
I: Colleen got a brand new computer and needed to install an operating system. Some friends recommended Windows, others Linux.
aB: Colleen found [commercial/open source] products more trustworthy.
nB: Colleen didn't trust [commercial/open source] products.
T: So she [installed/didn't install] [Windows/Linux].

(9)
I: A man was rushed to the emergency room with a pierced lung and a head injury. The surgeon needed to decide what to operate on first.
aB: He thought that it was most critical to stabilize the [brain/respiratory] function.
nB: He thought it was not as critical to stabilize the [brain/respiratory] function.
T: So he [operated/didn't operate] on the [head/lung].

(10)
I: Frankie the Filch wanted to pull off one last heist before his retirement. The bank and the jeweler seemed good targets.
aB: [Diamonds/Money] would be easier to transport.
nB: [Diamonds/Money] woud not be easy to transport.
T: So Frankie [robbed/didn't rob] the [jeweler/bank].

(11)
I: George and Lisa had booked a trip to Rome, but suddenly the travel agency cancelled the trip. The agency gave them a choice to visit either London or Paris instead.
aB: George was more excited about visiting [England/France].
nB: George wasn't as excited about visiting [England/France].
T: So they [traveled/didn't travel] to [London/Paris].

(12)
I: Ellen’s friend was leaving the country and looking for someone to adopt his cat and his bird. Ellen wanted to help, but she could keep only one of the animals.
aB: She thought she would find the sound of [purring/singing] more pleasant.
nB: She thought she would not really like the sound of [purring/singing].
T: So she [adopted/didn't adopt] the [cat/bird].

(13)
I: During the Olympic Summer Games, the President gave a speech to the United Nations. CBS needed to choose between broadcasting the Olympics or the speech during primetime.
aB: They expected viewers to be more interested in [sports/politics].
nB: They expected viewers not to care as much about [sports/politics].
T: Therefore they [broadcast/didn't broadcast] the [Olympics/speech].

(14)
I: Prof. Emmons was giving a statistics midterm. He considered allowing either the book or a sheet of notes during the exam.
aB: He thought the [hand-written/typeset] materials presented a better option.
nB: He thought the [hand-written/typeset] materials would not be such a good option.
T: Thus he [allowed/didn't allow] the [notes/book].

(15)
I: The convict asked for a review of his case. So the judge had to decide whether to uphold the conviction or to allow an appeal.
aB: The new evidence suggested that the convict was [innocent/guilty].
nB: The new evidence suggested that the convict was not [innocent/guilty].
T: Therefore the judge [approved/didn't approve] the [appeal/conviction].

(16)
I: Amy was lost, but fortunately there were several people whom she could ask for directions. She wondered whether to ask the mailman or an officer.
aB: A [letter carrier/cop] would surely know the area well.
nB: A [letter carrier/cop] would probably not know the area as well.
T: So she [asked/didn't ask] the [mailman/officer].

(17)
I: The twins received a box of Legos for their birthday. The instructions showed how they could build a castle or a jet.
aB: The twins wanted to pretend they were [pilots/royalty].
nB: The twins didn't want to play [pilots/royalty].
T: So they [assembled/didn't assemble] the [jet/castle].

(18)
I: The National Science Foundation offered a large grant for the sciences. The top applications came from a famous physicist and an equally famous biologist.
aB: The NSF thought the money should go to studying [gravity/cells].
nB: The NSF thought the money should not go to studying [gravity/cells].
T: Thus they [awarded/didn't award] the grant to the [physicist/biologist].

(19)
I: The City Park was frequently used by both mountain bikers and horseback riders. But because of excessive trail damage, the park administration deliberated on whether to ban bikes or horses.
aB: Most members felt that the [hooves/tires] did more damage.
nB: Most members felt that the [hooves/tires] didn't do much damage.
T: Therefore they [banned/didn't ban] [horses/bikes].

(20)
I: Tim went to the park to sit on the grass and read a book. There were some nice spots both in the shade and in the sun.
aB: Tim preferred a [hotter/cooler] spot.
nB: Tim didn't want to be in a [hotter/cooler] spot.
T: So he [sat/didn't sit] in the [sun/shade].

(21)
I: The newly hired exterminator had removed an ant infestation in a rental apartment. He wasn't sure whether to bill the landlord or the tenant for his services.
aB: He figured that the [occupant/owner] was responsible for maintenance.
nB: He figured that the [occupant/owner] was not responsible for maintenance.
T: So he [billed/didn't bill] the [tenant/landlord].

(22)
I: Debbie discovered that both the raspberries and the peppers in her garden were very ripe. Unfortunately she didn't have enough time to harvest both before going to work.
aB: She had heard that too much time on the vine was more dangerous for [fruit/vegetables].
nB: She had heard that a long time on the vine didn't affect [fruit/vegetables] too much.
T: So she [harvested/didn't harvest] the [raspberries/peppers].

(23)
I: Francine had seen her neighbors' teenage son vandalize her car. She had the cell phone numbers of both his mother and the father.
aB: A [woman/man] would probably respond more reasonably to her complaint.
nB: A [woman/man] would probably not respond very reasonably to her complaint.
T: So she [complained/didn't complain] to the [mother/father].

(24)
I: Tracy's parents were going to paint her room. There was a sale on yellow and blue paints.
aB: Tracy wanted her room to look like the [sun/sky].
nB: Tracy didn't want her room to look like the [sun/sky].
T: So they [painted/didn't paint] her room [yellow/blue].

(25)
I: The fugitives that the police were chasing vanished at the end of a dead-end street. To the left was a junkyard, and to the right a park.
aB: The [cars/trees] seemed to be a better hideout.
nB: The [cars/trees] didn't seem to be a particularly good hideout.
T: So the police [searched/didn't search] the [junkyard/park].

(26)
I: Beth studied the menu at a new restaurant. Only the steak and the salmon sounded tasty.
aB: Beth was in the mood for some [fish/beef].
nB: Beth was not really in the mood for [fish/beef].
T: So she [ordered/didn't order] the [salmon/steak].

(27)
I: A sports journalist was preparing an inside report on a successful baseball team. She had the opportunity to interview either the team's manager or the coach.
aB: At this point, she needed more information about [business matters/training methods].
nB: At this point, she didn't need information about [business matters/training methods] anymore.
T: Hence she [interviewed/didn't interview] the [manager/coach].

(28)
I: Tom was desperate: he would never finish all of his homework. He had to write an essay on Shakespeare and a program in C++.
aB: In the end, his [English/Computer Science] grades were more important to him.
nB: In the end, his [English/Computer Science] grades were not as important to him.
T: So he [wrote/didn't write] the [essay/program].

(29)
I: Caltrans was planning a new road that was to cross a canal. They looked into the costs of building either a tunnel underneath the canal or a bridge over it.
aB: Having the road go [over/under] the canal was more economical.
nB: Having the road go [over/under] the canal was not very economical.
T: Therefore they [built/didn't build] a [bridge/tunnel].

(30)
I: During his long flight, John needed a snack. The flight attendant could only offer him pretzels or cookies.
aB: John wanted something [salty/sweet].
nB: John didn't want anything [salty/sweet].
T: So he [bought/didn't buy] the [pretzels/cookies].

(31)
I: Brian didn't want to carry too much on his backpacking trip. He was trying to decide between taking a stove or a lantern.
aB: He thought [cooking equipment/a light source] would be more useful.
nB: He thought [cooking equipment/a light source] was not really essential.
T: So he [packed/didn't pack] the [stove/lantern].

(32)
I: Patricia received two wedding proposals in the same week. One was from a banker, the other from an artist.
aB: Patricia wanted [a conventional/an alternative] lifestyle.
nB: Patricia didn't want [a conventional/an alternative] lifestyle.
T: Thus she [chose/didn't choose] the [banker/artist].

(33)
I: Burt was in the woods hunting for his dinner. At the same instant, he spotted both a turkey and a deer.
aB: Burt really liked [fowl/game].
nB: Burt was not very fond of [fowl/game].
T: So he [shot/didn't shoot] the [turkey/deer].

(34)
I: Lynn was determined to bring some order into her life. This weekend, she vowed to rearrange either her clothes or her books.
aB: The disorder [in the closet/on the shelf] had been bothering her for a while.
nB: The disorder [in the closet/on the shelf] had not been bothering her so far.
T: So she [sorted/didn't sort] her [clothes/books].

(35)
I: A cosmetics company had just developed a new shampoo and a new lotion. They needed to decide which product to release first.
aB: Research suggested that that the market was ripe for a new [hair/skin] product.
nB: Research suggested that the market was not ripe for a new [hair/skin] product.
T: Therefore the company [released/didn't release] the [shampoo/lotion].

(36)
I: Gavin was doing poorly in Calculus and in Genetics. He couldn't drop both classes because of financial aid considerations.
aB: He thought he could do better with the [math/biology] course some other time.
nB: He knew he wouldn't ever do any better with the [math/biology] course.
T: Hence he [dropped/didn't drop] [Calculus/Genetics].

(37)
I: The British squadron leader had identified two potential targets. There was a German airfield and a large shipyard within bomber range.
aB: He figured that the Germans would be more affected by the loss of their [planes/submarines].
nB: He figured that the Germans would not be as affected by the loss of their [planes/submarines].
T: Hence the British [bombed/didn't bomb] the [airfield/shipyard].

(38)
I: Tim’s laptop had only one USB port. So he couldn’t connect his external keyboard and monitor at the same time.
aB: Tim was very worried about his [wrists/eyes].
nB: Tim was not all too worried about his [wrists/eyes].
T: So he [connected/didn't connect] the [keyboard/monitor].

(39)
I: After the earthquake people took shelter at the supermarket and at the museum. FEMA, however, sent only one bus - enough to evacuate one of the structures.
aB: The risk of being hurt from falling [groceries/artifacts] was considered especially severe.
nB: The risk of being hurt from falling [groceries/artifacts] was not considered especially severe.
T: Therefore FEMA [evacuated/didn't evacuate] the [supermarket/museum].

(40)
I: Mike’s car made strange noises when driving downhill. His mechanic suspected a problem with the brakes or with the transmission.
aB: Mike said that the car also seemed to have trouble [stopping/shifting].
nB: Mike said the car hadn't ever had any trouble [stopping/shifting].
T: So the mechanic [examined/didn't examine] the [brakes/transmission].

(41)
I: Just before leaving for the airport, Sally remembered to take some sunscreen and an umbrella. Unfortunately, she couldn’t fit both items in her luggage.
aB: Sally was particularly afraid of getting [burned/wet].
nB: Sally was not very afraid of getting [burned/wet].
T: So she [grabbed/didn't grab] the [sunscreen/umbrella].

(42)
I: Sarah was preparing a soup. The recipe suggested adding either lemon or some jalapenos.
aB: Sarah liked a hint of [sourness/spicyness].
nB: Sarah didn't really like [sourness/spicyness] in her food.
T: So she [added/didn't add] any [lemon/jalapenos].

(43)
I: One of the members of a safari party shot an endangered bird. The authorities deliberated whether to fine the hunter himself or the guide of the safari.
aB: They decided that the person who [shot the bird/organized the trip] was more at fault.
nB: They decided that the person who [shot the bird/organized the trip] was not really to blame.
T: Hence they [fined/didn't fine] the [hunter/guide].

(44)
I: Winnie scheduled a meeting with the editor of the children's book she was working on. By then, she needed to finish at least one aspect of the book: the illustrations or the story.
aB: The editor had always appeared more interested in the [pictures/text].
nB: The editor didn't appear all that interested in the [pictures/text].
T: Hence Winnie [finished/didn't finish] the [illustrations/story].

(45)
I: Over Christmas, Paula wanted to visit her relatives abroad. Some of them lived in Canada, and some in Mexico.
aB: Paula wanted to see some [sun/snow].
nB: Paula didn't really care about [sun/snow].
T: So she [flew/didn't fly] to [Mexico/Canada].

(46)
I: Pam had a difficult decision to make. Should she follow her heart or her head?
aB: Pam had more faith in her [emotions/logic].
nB: Pam didn't have much faith in her [emotions/logic].
T: So she [followed/didn't follow] her [heart/head].

(47)
I: An aid organization had money earmarked for Guatemala. A hospital and an orphanage put in requests for the money.
aB: The situation of [children/medicine] in Guatemala was considered extremely serious.
nB: The situation of [children/medicine] in Guatemala was not considered very serious.
T: Therefore the organization [helped/didn't help] the [orphanage/hospital].

(48)
I: An actress-turned-nun decided to give away all her earthly possessions. She wanted just one keep-sake: her old violin or her favorite necklace.
aB: The [instrument/jewelry] had more sentimental value.
nB: The [instrument/jewelry] didn't have as much sentimental value.
T: So she [kept/didn't keep] the [violin/necklace].

(49)
I: The princess was looking for her enchanted prince to release him with a kiss. A snake and a beetle both claimed to be her beloved.
aB: The local witch was known for turning people into [insects/reptiles].
nB: The local witch usually didn't turn people into [insects/reptiles].
T: So the princess [kissed/didn't kiss] the [beetle/snake].

(50)
I: Ernest was making out his will. To his nephew, he wanted to leave the helicopter or the boat.
aB: The nephew already knew how to [fly/sail].
nB: The nephew didn't know how to [fly/sail].
T: Thus Ernest [left/didn't leave] him the [helicopter/boat].

(51)
I: The potter wanted to make a present for her daughter. She knew how to make either a bowl or a vase.
aB: Her daughter needed something to put [fruit/flowers] in.
nB: Her daughter didn't need any more containers for [fruit/flowers].
T: So the potter [made/didn't make] a [bowl/vase].

(52)
I: The ice sculptor was going to take part in the annual competition. He had already made sketches for an angel and for a devil.
aB: In the end, the sculptor wished to portray pure [goodness/evil].
nB: The sculptor was not interested in portraying [goodness/evil].
T: So he [made/didn't make] the [angel/devil].

(53)
I: Everything Martin owned seemed to be broken. This weekend, he was finally going to fix the radio or the blender.
aB: Martin really looked forward to [having smoothies/listening to music] again.
nB: Martin didn't care so much about [having smoothies/listening to music].
T: Therefore he [fixed/didn't fix] the [blender/radio].

(54)
I: Gina had to write a research paper for her Religious Studies class. She could research either Catholicism or Buddhism.
aB: Gina was more interested in [Christian practices/Eastern religions].
nB: Gina was not very interested in [Christian practices/Eastern religions].
T: Therefore she [investigated/didn't investigate] [Catholicism/Buddhism].

(55)
I: In high school, Rob had excelled at swimming and soccer. In college, he wanted to concentrate his energies on only one sport.
aB: Rob felt most at home [in the pool/on the field].
nB: Rob didn't really want to spend all his time [in the pool/on the field].
T: Thus he [focused/didn't focus] on [swimming/soccer].

(56)
I: On her birthday, Jane received an envelope and a package. Which one should she open first?
aB: Jane was eager to [read the letter/see her gift].
nB: Jane wasn't quite as excited about the [letter/gift].
T: So she [opened/didn't open] the [envelope/package].

(57)
I: Sue was feeling depressed and wanted to talk to someone. Should she call her therapist or her sister?
aB: Sue thought a [professional/family member] would be more helpful.
nB: Sue thought a [professional/family member] would not be as helpful.
T: So she [called/didn't call] her [therapist/sister].

(58)
I: Tony won a car on a game show. He could choose between a minivan and a convertible.
aB: Tony wanted a [family vehicle/sports car].
nB: Tony didn't need a [family vehicle/sports car].
T: So he [picked/didn't pick] the [minivan/convertible].

(59)
I: William had inherited some fertile land in California. He was advised to plant either almonds or grapes.
aB: William liked the idea of being a [nut farmer/wine maker].
nB: William could not imagine being a [nut farmer/wine maker].
T: Hence he [grew/didn't grow] [almonds/grapes].

(60)
I: Matthew was visiting his friend Jimmy. Jimmy suggested that they play with his legos or with his Nintendo.
aB: Matthew liked [video games/constructing things].
nB: Matthew was not really into [video games/constructing things].
T: So the boys [played/didn't play] with the [Nintendo/legos].

(61)
I: As usual, Professor Myers had planned to do too many things in one day. It was 8pm, and she had to decide whether to prepare her lecture or an experiment for tomorrow.
aB: Her university valued [teaching/research] more highly.
nB: Her university didn't value [teaching/research] as much.
T: Hence Professor Myers [prepared/didn't prepare] the [lecture/experiment].

(62)
I: Everyone at table 5 had finished the main course. The waiter was trying to size up whether they would want to get the bill or revisit the menu.
aB: The guests seemed to want to [pay/order dessert].
nB: The guests didn't appear very eager to [pay/order dessert].
T: So the waiter [presented/didn't present] them the [bill/menu].

(63)
I: The newspaper editor was working on the next day’s front page. For the space above the fold he was considering either a photo or another article.
aB: The readership seemed to appreciate [visual content/written information] a lot.
nB: The readership didn't seem to appreciate [visual content/written information] very much.
T: So the editor [printed/didn't print] the [photo/article].

(64)
I: David wanted a scooter and a laptop for his graduation. But his parents told him they couldn’t afford to get him both gifts.
aB: They thought that [transportation/internet access] would be more important for David.
nB: They thought that [transportation/internet access] would not be that important for David.
T: Hence they [promised/didn't promise] him the [scooter/laptop].

(65)
I: Greta and Paul wanted a new desk and a new couch. They couldn’t afford to purchase both at the same time.
aB: They had planned to upgrade the [home office/living room] first.
nB: The upgrade of the [home office/living room] was not a priority.
T: So they [purchased/didn't purchase] the [desk/couch].

(66)
I: On one of his journeys, Alistair the time-traveler glimpsed a unicorn and a dragon. He wanted to capture one of the creatures and take it back to the 21st century.
aB: Modern people would probably pay a lot to see the [horse/dinosaur]-like creature.
nB: Modern people would probably not pay too much to see the [horse/dinosaur]-like creature.
T: Therefore Alistair [pursued/didn't pursue] the [unicorn/dragon].

(67)
I: Violet was nearing the end of her horseback ride. She wondered whether to put the horse in the stable or in the pasture.
aB: She thought the horse might want [fresh grass/shelter].
nB: The horse didn't seem to need [fresh grass/shelter] yet.
T: So Violet [put/didn't put] the horse in the [pasture/stable].

(68)
I: Pacific College had been receiving very few applicants. The administration considered lowering either the tuition or the requirements for admission.
aB: Students would be more responsive to the [financial/academic] changes.
nB: Students would probably not respond to the [financial/academic] changes.
T: Therefore the administration [lowered/didn't lower] the [tuition/requirements].

(69)
I: Samantha wanted to borrow a CD from her uncle’s diverse collection. Her uncle recommended that she should listen to Mozart or Eminem.
aB: Samantha liked [classical music/rap].
nB: Samantha didn't like [classical music/rap].
T: So she [borrowed/didn't borrow] the [Mozart/Eminem].

(70)
I: Tom wanted to rent a movie and asked his friends for advice. One of them recommended a documentary, another a thriller.
aB: Tom was in the mood for [an educational/a suspenseful] film.
nB: Tom was not really in the mood for [an educational/a suspenseful] film.
T: So he [rented/didn't rent] the [documentary/thriller].

(71)
I: The city of San Diego needed to repair both the sewers and the roads in North Park. The city budget, however, was too tight to do both.
aB: The city had received many complaints about [wastewater problems/potholes].
nB: Unlike many other issues, the [wastewater problems/potholes] had not caused any citizen complaints.
T: Therefore the city [repaired/didn't repair] the [sewers/roads].

(72)
I: The blouse and slacks that Cynthia had bought really didn’t go well together. She decided to return one of the two items.
aB: Cynthia already had more than enough [tops/pants].
nB: Cynthia didn't have enough [tops/pants].
T: So she [returned/didn't return] the [blouse/slacks].

(73)
I: The comedian needed to refer to a prominent public figure for his current joke to work. Either the Pope or the President would serve perfectly.
aB: Jokes about [religious figures/politicians] always went over well.
nB: Jokes about [religious figures/politicians] didn't always go over well.
T: So the comedian [ridiculed/didn't ridicule] the [Pope/President].

(74)
I: The field of Halloween costume contestants had been narrowed down to two contestants. The judges had to choose between a werewolf and a mermaid.
aB: They felt that the [furry pelt/fishlike tail] looked more realistic.
nB: They felt that the [furry pelt/fishlike tail] didn't look very realistic.
T: Thus they [selected/didn't select] the [werewolf/mermaid].

(75)
I: Stella and Felix were planning their wedding. They wanted to serve only one meal to their guests - lunch or dinner.
aB: People would probably be starving [at noon/in the evening].
nB: People would probably not be very hungry [at noon/in the evening].
T: Hence they [served/didn't serve] [lunch/dinner].

(76)
I: Bill’s sister Cindy had stopped by to spend the afternoon with him. Bill wanted to show her his favorite gallery or the city park.
aB: Cindy wanted to [see some art/go for a walk].
nB: Cindy didn't want to [see art/go for a walk].
T: So Bill [took/didn't take] her to the [gallery/park].

(77)
I: When the convenience store clerk went to the bathroom, Tommy saw his chance. He had just enough time to shoplift either a bottle of whiskey or a carton of cigarettes.
aB: Tommy liked [drinking/smoking].
nB: Tommy was not into [drinking/smoking].
T: So he [stole/didn't steal] any [whiskey/cigarettes].

(78)
I: Ally wanted to visit her family in Los Angeles. Since she didn’t own a car, she could either take the train or the bus.
aB: She had always been satisfied with the [Amtrak/Greyhound] service.
nB: She had no great liking for the [Amtrak/Greyhound] service.
T: Therefore she [took/didn't take] the [train/bus].

(79)
I: Mrs. Robinson’s Kindergarten class was making Valentines. She only wanted to put out one type of crafts supply - scissors or crayons.
aB: She thought that [cutting out/coloring] the hearts would be easier for the students.
nB: She thought the students would not succeed in [cutting out/coloring] the hearts.
T: So she [put/didn't put] out the [scissors/crayons].

(80)
I: A politician was contemplating the topic for his upcoming TV spot. He could talk about the environment or the economy.
aB: His constituents had expressed concern about the loss of [wildlife habitat/jobs].
nB: His constituents had not expressed much concern about the loss of [wildlife habitat/jobs].
T: Therefore he [talked/didn't talk] about the [environment/economy].

(81)
I: Mary was invited to a potluck dinner. She wondered whether she should bring a cake or a salad.
aB: Then Mary thought that something [sweet/healthy] would probably be appreciated.
nB: Then Mary thought people would probably not appreciate anything [sweet/healthy].
T: So she [brought/didn't bring] a [cake/salad].

(82)
I: Sally wanted to finally use up the flour she had bought a while ago. She figured she could bake either some bread or some brownies.
aB: Her family really enjoyed [sandwiches/dessert].
nB: Her family didn't really like [sandwiches/dessert].
T: So Sally [baked/didn't bake] any [bread/brownies].

(83)
I: Paul had about an hour of free time. This was a chance to finish reading his novel or the magazine he had started last week.
aB: Right now, Paul was in the mood for some [fiction/gossip].
nB: Right now, Paul was not in the mood for [fiction/gossip].
T: So he [read/didn't read] the [novel/magazine].

(84)
I: Annie was preparing dinner. She wondered whether she should have chicken or tofu along with her vegetables.
aB: Annie wanted some [animal/soy] protein.
nB: Annie did not want any [animal/soy] protein.
T: Hence she [had/didn't have] any [chicken/tofu].

(85)

I: The theater troupe was discussing what kind of piece they would perform at the festival. Some preferred a tragedy, others a comedy.
aB: The festival audience would probably like something [funny/serious].
nB: The festival audience might not like a [funny/serious] play.
T: Therefore the troupe [performed/didn't perform] a [comedy/tragedy].

(86)

I: A group of friends was having a game night. They were argueing about whether they should play poker or monopoly.
aB: Most of them preferred [card/board] games.
nB: Most of them didn't like [card/board] games as much.
T: So they [played/didn't play] [poker/monopoly].

(87)

I: Sue and Peter were discussing their wedding dance. Their dance instructor had suggested that they go with either a tango or a polka.
aB: Sue and Peter wanted something [romantic/lively].
nB: Sue and Peter didn't want anything too [romantic/lively].
T: So they [danced/didn't dance] a [tango/polka].

(88)

I: Claudia and Tim wanted to spend the weekend in Santa Barbara. They wondered whether to book a campsite or a room for the night.
aB: Claudia preferred sleeping [outdoors/in a hotel].
nB: Claudia didn't want to sleep [outdoors/in a hotel].
T: So they [booked/didn't book] a [campsite/room].

(89)

I: A woman had shot her husband. The prosecutor was weighing whether to charge her with murder or just manslaughter.
aB: The evidence suggested that the killing was [premeditated/accidental].
nB: The evidence suggested that the killing was not [premeditated/accidental].
T: Therefore the prosecutor [charged/didn't charge] her with [murder/manslaughter].

(90)

I: Susan had invited some of her friends for dinner. She wanted to cook something spicy like a chili or a curry.
aB: Her friends all liked [Indian/Mexican] food.
nB: Her friends were not crazy about [Indian/Mexican] food.
T: Hence Susan [cooked/didn't cook] a [curry/chili].

(91)

I: Chris had received two equally attractive job offers. Now he just had to decide whether he wanted to live in Houston or Miami.
aB: Chris had heard good things about life in [Texas/Florida].
nB: Chris had not heard anything good about life in [Texas/Florida].
T: So he [moved/didn't move] to [Houston/Miami].

(92)
I: Sandra had been performing so well at work that her boss wanted to reward her. He was alternating between offering her a raise or an office of her own.
aB: Sandra seemed very concerned about [her work environment/money].
nB: Sandra didn't seem very concerned about [her work environment/money].
T: Thus her boss [offered/didn't offer] her the [office/raise].

(93)
I: Ian desperately needed some caffeine. He went to the kitchen and found some coke and some coffee.
aB: Ian wanted something [hot/cold].
nB: Ian didn't want anything [hot/cold].
T: So he [drank/didn't drink] any [coffee/coke].

(94)
I: Benjamin wanted to submit a musical composition to a national competition. He wondered whether he should write a song or a concerto for clarinet.
aB: Traditionally, the jury seemed to score [vocal/instrumental] music higher.
nB: The jury didn't seem to score [vocal/instrumental] music as highly.
T: Therefore Benjamin [composed/didn't compose] a [song/concerto].

(95)
I: Paula and Gwen wanted to go out on a Saturday night. They considered going to the theatre or to the symphony.
aB: Paula was in the mood for [a play/music].
nB: Paula was not really in the mood for [a play/music].
T: So they [went/didn't go] to the [theatre/symphony].

(96)
I: Hank needed to wash his towels and his sheets. As he only had enough quarters to do one load of laundry, he couldn’t wash both.
aB: Hank was obsessed when it came to cleanliness [after showering/while sleeping].
nB: Hank was not too concerned when it came to cleanliness [after showering/while sleeping].
T: Thus he [washed/didn't wash] his [towels/sheets].

(97)
I: Kathy considered herself an Independent voter. The only two candidates for mayor were a Republican and a Democrat.
aB: Kathy's views were more in line with [conservative/liberal] policies.
nB: Kathy's views were not especially in line with most [conservative/liberal] policies.
T: So she [voted/didn't vote] for the [Republican/Democrat].

(98)
I: Rita inherited an empty building on Main Street. Her friends suggested that it was a perfect place for a restaurant or a gym.
aB: Rita already knew how to manage [a dining/an athletic] establishment.
nB: Rita didn't have a clue of how to manage [a dining/an athletic] establishment.
T: Hence she [turned/didn't turn] it into a [restaurant/gym].

(99)
I: Larry got reception for only two TV stations. This evening he had the choice between a sitcom and the news.
aB: Larry wanted to see something [funny/informative].
nB: Larry didn't care much for [funny/informative] programs.
T: Hence he [watched/didn't watch] the [sitcom/news].

(100)
I: Vicky and the other kids were playing hide-and-seek in the garden. Vicky had to decide quickly whether to hide in the greenhouse or in the shed.
aB: She thought that it would be easier to hide amidst the [plants/tools].
nB: She thought that it would not be easy to hide amidst the [plants/tools].
T: Thus she [hid/didn't hide] in the [greenhouse/shed].

(101)
I: Joe had several boxes with old books that he needed to store somewhere. There was some space in the attic and in the basement.
aB: Joe preferred to carry the boxes [upstairs/downstairs].
nB: Joe didn't want to carry the boxes [upstairs/downstairs].
T: So he [stored/didn't store] them in the [attic/basement].

(102)
I: Nina had been assigned a tiny part of the garden in front of her apartment building. She considered planting roses or beans in her plot.
aB: Having fresh [flowers/vegetables] sounded more exciting.
nB: She didn't really need [flowers/vegetables] in front of the house.
T: So Nina [planted/didn't plant] any [roses/beans].

(103)
I: Herbert had several overdue bills, including one from his doctor and one from his lawyer. Given his financial situation, he couldn't afford to pay both immediately.
aB: Herbert thought he might soon need [medical/legal] services again.
nB: Herbert didn't expect to need [medical/legal] services anytime soon.
T: Therefore he [paid/didn't pay] his [doctor/lawyer].

(104)
I: Tracy went through her closet to find something to wear at the garden party. She found a dress and a pair of jeans that she liked.
aB: Something [practical/feminine] would probably be appropriate.
nB: Something too [practical/feminine] would probably not be appropriate.
T: So she [put/didn't put] on the [jeans/dress].

(105)
I: Jarred had been selected to give a speech at graduation. He wasn't sure whether to talk about the past or the future.
aB: Graduation seemed to be a good opportunity to look [back/ahead].
nB: Graduation didn't seem the right time for looking [back/ahead].
T: Thus Jarred [talked/didn't talk] about the [past/future].

(106)
I: Emily finally needed to declare a major. She considered both English and Physics.
aB: She was more interested in [science/humanities].
nB: She was not excited enough about [science/humanities].
T: Therefore she [majored/didn't major] in [Physics/English].

(107)
I: Daniel wanted to go into a medical profession. He considered going into optometry or dentistry.
aB: He liked the idea of fixing people’s [eyesight/teeth].
nB: He didn't really want to deal with people's [eyesight/teeth].
T: Hence he [went/didn't go] into [optometry/dentistry].

(108)
I: Mark’s girlfriend wanted to get him an unusual birthday present. She offered to buy him either an earring or a tattoo.
aB: Mark had always dreamed of [getting a piercing/decorating his skin].
nB: Mark could not stand the idea of [getting a piercing/decorating his skin].
T: So he [opted/didn't opt] for the [earring/tattoo].

(109)
I: Kathleen was at a party. The host offered to get her a beer or a soda.
aB: Kathleen was in the mood for something [with alcohol/sweet].
nB: Kathleen was not in the mood for anything [with alcohol/sweet].
T: So she [asked/didn't ask] for a [beer/soda].

(110)
I: Ralph wanted to buy a Christmas present for his dad. In the bookstore he found a dictionary and an atlas that would do the trick.
aB: His father had always been fond of [words/maps].
nB: His father didn't care too much about [words/maps].
T: Therefore Ralph [purchased/didn't purchase] the [dictionary/atlas].

(111)
I: Ester wanted to make something for her granddaughter Lisa. She thought about knitting mittens or socks.
aB: Lisa often complained about cold [hands/feet].
nB: Lisa had never complained about cold [hands/feet].
T: So Ester [knitted/didn't knit] her any [mittens/socks].

(112)
I: Pamela had hoped to wear some jewelry for her night at the opera. Her husband said that wearing both a ring and a bracelet would be too gaudy.
aB: Pamela wanted to draw attention to her [fingers/wrist].
nB: Pamela didn't really want to draw too much attention to her [fingers/wrist].
T: So she [wore/didn't wear] the [ring/bracelet].

(113)
I: Lewis wanted to order something from a catalog. The instructions said he could send the form by regular mail or by fax.
aB: He thought the [electronic method/postal service] was more convenient.
nB: He thought the [electronic method/postal service] was not very convenient.
T: Hence he [sent/didn't send] it by [fax/mail].

(114)
I: Mia wanted to sign up for a crafts class. Only sewing and ceramics were still available.
aB: Mia had always wanted to make her own [clothes/pottery].
nB: Mia didn't have any interest in making [clothes/pottery].
T: Thus she [signed/didn't sign] up for [sewing/ceramics].

(115)
I: The settlers wanted to build a new settlement in another valley. They knew how to build the houses out of brick or wood.
aB: There [was a lot of clay/were a lot of trees] nearby.
nB: There [wasn't any clay/weren't any trees] nearby.
T: Therefore the settlers [built/didn't build] with [brick/wood].

(116)
I: Gerald was in debt and urgently needed some money. He could sell his piano or his car.
aB: Gerald suspected that the [instrument/vehicle] would sell for more.
nB: Gerald suspected that he would not get a good price for the [instrument/vehicle].
T: So he [advertised/didn't advertise] the [piano/car].

(117)
I: Phil wanted to join the choir or the band at his school. Unfortunately, because of scheduling conflicts, he couldn’t join both.
aB: Phil was most excited about [singing/playing an instrument].
nB: Phil wasn't quite as excited about [singing/playing an instrument].
T: Hence he [joined/didn't join] the [choir/band].

(118)
I: Vanessa went to the woods to find a suitable subject for a detailed drawing. She saw a squirrel and an orchid that would be good to draw.
aB: Her arts teacher really adored [animals/plants].
nB: Her arts teacher didn't relish [animals/plants].
T: Therefore Vanessa [drew/didn't draw] the [squirrel/orchid].

(119)
I: A poor farmer had almost run out of food for his animals. He had to choose between feeding his cows or his chickens.
aB: The farmer needed his source of [eggs/milk].
nB: He would not miss his source of [eggs/milk] too badly.
T: So he [fed/didn't feed] the [chickens/cows].

(120)

I: Gina stopped by a shop to buy a small gift for her sick aunt. Having only one dollar in her wallet, she could afford to buy only a newspaper or some candy.

aB: Her aunt would surely like something to [read/eat].

nB: Her aunt would not really need anything too [read/eat].

T: Hence Gina [bought/didn't buy] the [newspaper/candy].

APPENDIX B:

ADDITIONAL TESTING MATERIALS

This appendix contains the Edinburgh handedness inventory, testing materials for the neutral and the interference condition of the Stroop test, as well as the two questionnaires with the Author Recognition Test and the Magazine Recognition Test.

ASSESSMENT OF HANDEDNESS

Code ____ Age ________ Sex ________

Please indicate your preferences in the use of hands in the following activities by putting a plus [+] in the appropriate column. Where the preference is so strong that you would never try to use the other hand unless absolutely forced to, put two plusses [++]. If in any case you are really indifferent put a plus [+] in both columns.

Some of the activities require both hands. In these cases the part of the task, or object, for which hand-preference is wanted is indicated in parentheses.

Please try to answer all the questions, and only leave a blank if you have no experience at all with the object or task.

	R	L
1. Writing	____	____
2. Drawing	____	____
3. Throwing	____	____
4. Scissors	____	____
5. Comb	____	____
6. Toothbrush	____	____
7. Knife (without spoon)	____	____
8. Spoon	____	____
9. Hammer	____	____
10. Screwdriver	____	____
11. Tennis racket	____	____
12. Golf club (lower hand)	____	____
13. Broom (upper hand)	____	____
14. Rake (upper hand)	____	____
15. Striking match (match)	____	____
16. Opening box (lid)	____	____
17. Dealing cards (card being dealt)	____	____
18. Threading needle (whichever is moved)	____	____
19. Which foot do you prefer to kick with?	____	____
20. Which eye do you use when only using one?	____	____

Please check:

1. Do you consider yourself

   ____ right-handed? ____ left-handed ____ambidextrous?

2. Is there anyone in your family (blood relations) who is left-handed?

   ____ yes ____ no If yes, please list relationship:________________________________

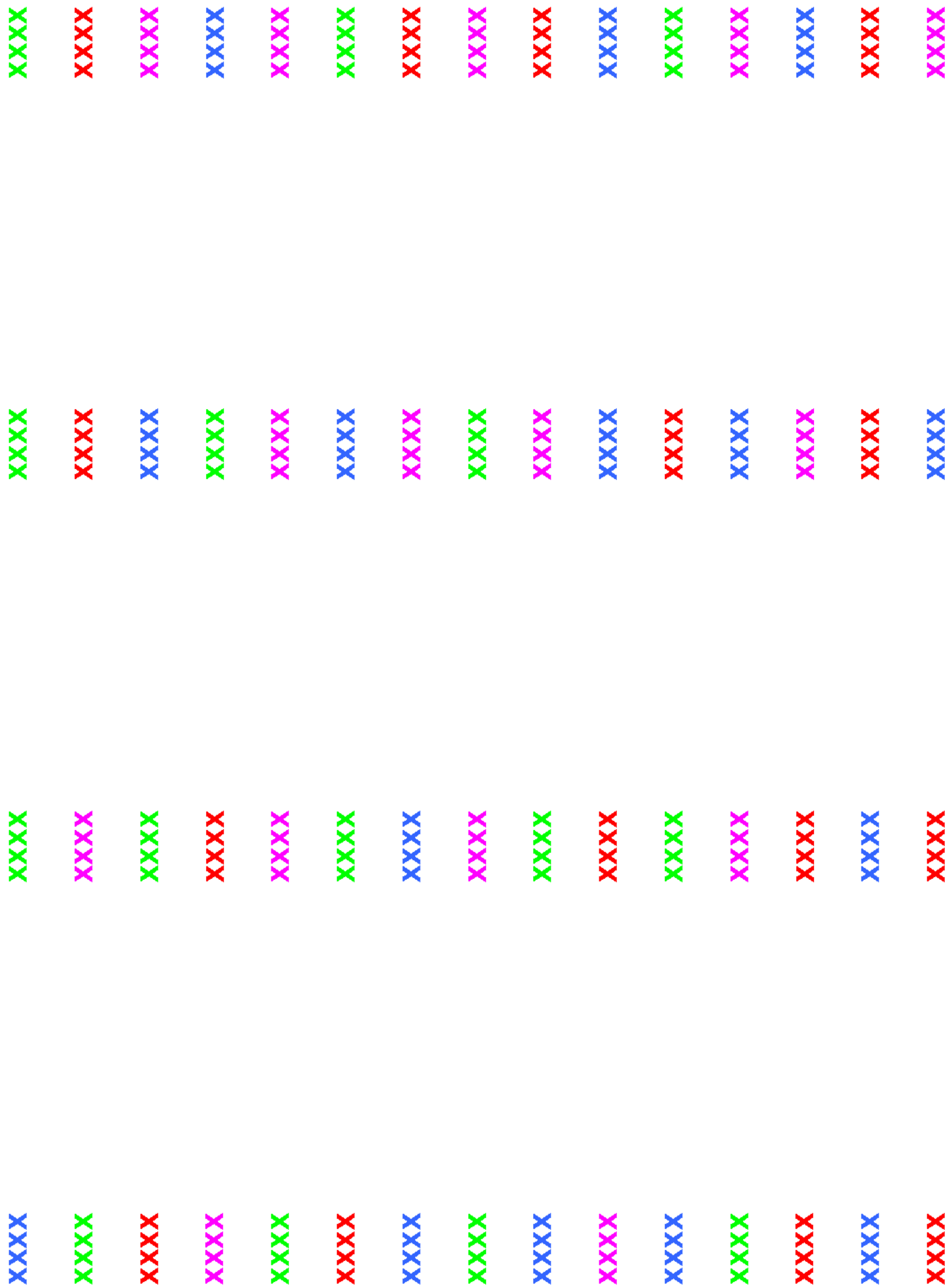
3. Did you ever change your handedness?

   ____ yes ____ no If yes, when and why:____________________________________

4. Is there any activity not in this list for which you would consistently use your non-dominant hand?

   ____ yes ____ no If yes, please list:______________________________________

Stroop (Neutral)



Stroop (Interference)

pink red green blue pink red pink blue blue green red green pink pink green

green blue green blue pink red blue red green red red red blue pink green

pink green red blue pink green pink pink blue pink red blue green red blue

red green red blue blue pink blue green green pink pink red green red blue

Author Recognition Questionnaire

Below you will see a list of 80 names. Some of the people in the list are popular writers (of books, magazine articles, and/or newspaper columns) and some are not. You are to read the names and put a check mark next to the names of those individuals who you know to be writers. Do not guess, but only check those who you know to be writers. Remember, some of the names are people who are not popular writers, so guessing can easily be detected.

1. Marilyn Jager Adams ____
2. Richard Allington ____
3. Donna Alvermann ____
4. Maya Angelou ____
5. Isaac Asimov ____
6. Kathryn Au ____
7. Rebecca Barr ____
8. Isabel Beck ____
9. Judy Blume ____
10. Erma Bombeck ____
11. Hilda Borko ____
12. Bertram Bruce ____
13. P. E. Bryant ____
14. Robert Calfee ____
15. Barbara Cartland ____
16. Carlos Castaneda ____
17. Jeanne Chall ____
18. Tom Clancy ____
19. Arthur C. Clarke ____
20. James Clavell ____
21. Theodore Clymer ____
22. Max Coltheart ____
23. Stephen Coonts ____
24. Priscilla Drum ____
25. Gerald Duffy ____
26. Dolores Durkin ____
27. Robert Dykstra ____
28. John Elkins ____
29. Roger Farr ____
30. Ian Fleming ____
31. James Flood ____
32. Dick Francis ____
33. Ruth Garner ____
34. Jack Goody ____
35. Stephen J. Gould ____
36. Michael Graves ____
37. Andrew Greeley ____
38. John Guthrie ____
39. David Halberstam ____
40. Alex Haley ____
41. Jane Hansen ____
42. Shirley Brice Heath ____
43. Frank Herbert ____
44. S. E. Hinton ____
45. John Jakes ____
46. Beau Fly Jones ____
47. Erica Jong ____
48. Michael Kamil ____
49. Stephen King ____
50. Dean Koontz ____
51. Judith Krantz ____
52. Louis L'Amour ____
53. Isabelle Liberman ____
54. Robert Ludlum ____
55. George McConkie ____
56. James Michener ____
57. P. David Pearson ____
58. Susanna W. Pflaum ____
59. Sylvia Porter ____
60. Keith Rayner ____
61. Nelson Rodriguez-Trujillo ____
62. Nancy Roser ____
63. S. Jay Samuels ____
64. Sidney Sheldon ____
65. Danielle Steel ____
66. Barbara M. Taylor ____
67. Paul Theroux ____
68. Robert Tierney ____
69. Alvin Toffler ____
70. J. R. R. Tolkien ____
71. Barbara Tuchman ____
72. John Updike ____
73. Leon Uris ____
74. Richard Venezky ____
75. Irving Wallace ____
76. Alice Walker ____
77. Joseph Wambaugh ____
78. Samuel Weintraub ____
79. Tom Wolfe ____
80. Bob Woodward ____

Magazine Recognition Questionnaire

Below you will see a list of 80 titles. Some of them are the names of actual magazines and some are not. You are to read the names and put a check mark next to the names of those that you know to be magazines. Do not guess, but only check those that you know to be actual magazines. Remember, some of the titles are not those of popular magazines, so guessing can easily be detected.

1. American Journal Review ____
2. Analog Science Fiction ____
3. Architectural Digest ____
4. Architecture Today ____
5. Atlantic ____
6. Business Week ____
7. Byte ____
8. Car and Driver ____
9. Changing Times ____
10. Consumer Reports ____
11. Create ____
12. Digital Sound ____
13. Discover ____
14. Dow Jones Weekly Report ____
15. Down Beat ____
16. Ebony ____
17. Effervescence ____
18. Electrical & Mechanical News ____
19. Elliot ____
20. Esquire ____
21. Field & Stream ____
22. Fitness Today ____
23. Forbes ____
24. Future Forecast ____
25. Galactic Digest ____
26. Gentlemen's Quarterly ____
27. Girl Weekly ____
28. Harper's Magazine ____
29. Health & Life ____
30. Home & Yard ____
31. Home Finance ____
32. House & Garden ____
33. Hunters ____
34. Illustrated Science ____
35. Jet ____
36. Ladies Home Journal ____
37. Madame ____
38. Mademoiselle ____
39. Market Trends ____
40. McCall's Magazine ____
41. Modern Family ____
42. Mother and Child ____
43. Mother Earth News ____
44. Mother Jones ____
45. Motor Sports ____
46. Motor Trend ____
47. Mountain and Stream ____
48. Music Weekly ____
49. Neuberger Review ____
50. New Democrat ____
51. New Republic ____
52. New Yorker ____
53. Newsweek ____
54. Outdoor Times ____
54. Pacific World ____
56. Personal Computing ____
57. Personal Psychology ____
58. Popular Science ____
59. Psychology Today ____
60. Public Policy Review ____
61. Putnam's American Magazine ____
62. Reader's Choice ____
63. Redbook ____
64. Road & Track ____
65. Rolling Stone ____
66. Safeco News Service ____
67. Science Quest ____
68. Science Reader ____
69. Scientific American ____
70. Seventeen ____
71. Sports Illustrated ____
72. Stock and Bond Digest ____
73. Technology Digest ____
74. The Sporting News ____
75. Tools and Repair ____
76. Town & Country ____
77. Travel & Leisure ____
78. Trends America ____
79. Wellington's Home Digest ____
80. Wildlife Conservation ____

APPENDIX C:

CONTRASTS

When an experimental factor (Truth or Negation) interacted with the factor Electrode, four contrasts were tested to assess the shape of the effect's distribution. The Hemisphere contrast compared left and right electrode sides while ignoring midline electrodes. The Laterality contrast used a gradient from midline sites over medial and dorsal to lateral channels. For Anteriority the contrast was defined as a gradient from prefrontal to frontal to central to temporal-parietal to occipital electrodes. Finally, Centrality tested for differences between central and less central (i.e., more posterior and more anterior) electrode sites, with a gradient from central over frontal and temporal-parietal to prefrontal and occipital channels. The weights were chosen so that the differences between levels (such as midline – medial – dorsal – lateral for Laterality) were equal for a given contrast. Below, the weights used by the four contrasts are listed for the 26 electrode sites.

	Contrast			
Electrode	Hemisphere	Laterality	Anteriority	Centrality
MiPf	0	22	-51	-21
LLPf	1	-17	-51	-21
RLPf	-1	-17	-51	-21
LMPf	1	9	-51	-21
RMPf	-1	9	-51	-21
LDFr	1	-4	-25	5
RDFr	-1	-4	-25	5
LLFr	1	-17	-25	5
RLFr	-1	-17	-25	5
LMFr	1	9	-25	5
RMFr	-1	9	-25	5
LMCe	1	9	1	31
RMCe	-1	9	1	31
MiCe	0	22	1	31
MiPa	0	22	27	5
LDCe	1	-4	1	31
RDCe	-1	-4	1	31
LDPa	1	-4	27	5
RDPa	-1	-4	27	5
LMOc	1	9	53	-21
RMOc	-1	9	53	-21
LLTe	1	-17	27	5
RLTe	-1	-17	27	5
LLOc	1	-17	53	-21
RLOc	-1	-17	53	-21
MiOc	0	22	53	-21

APPENDIX D:

NEGATION AND QUANTIFICATION EFFECTS ON SENTENCE CLOZE

In order to assess negation effects on expectations about sentence continuations, we employed the cloze procedure (Taylor, 1953), in which subjects are asked to complete sentence fragments. In addition to negation, we also included quantifiers, since negative quantifiers appear to share many of the properties of *not*-negation (cf. Klima, 1964; Moxey & Sanford, 1993).

Participants

Eighty UCSD students participated for course credit or pay. All participants were native speakers of English, although some had been raised bilingual.

Materials

Two-hundred-sixty-two plural nouns were selected:

Accountants, Actors, Actresses, Adolescents, Adults, Advertisements, Airplanes, Alcoholics, Anchormen, Angels, Ants, Apes, Applicants, Aquariums, Archaeologists, Architects, Armies, Artists, Astronomers, Athletes, Attorneys, Authors, Automobiles, Babies, Bakers, Bands, Barbers, Bartenders, Beavers, Bees, Bellboys, Birds, Boxcars, Boys, Brides, Brokers, Burglars, Buses, Businessmen, Butchers, Butterflies, Buyers, Camels, Candidates, Candles, Carpenters, Cars, Cashiers, Caterers, Cats, Chefs, Children, Chimneys, Chimps, Choirs, Cleaners, Clients, Clouds, Clowns, Coaches, Comedians, Committees, Companies, Compliments, Computers, Concerts, Conferences, Convicts, Countries, Cowboys, Critics, Custodians, Customers, Dancers, Dentists, Detectives, Diagrams, Dictators, Dictionaries, Directors, Doctors, Dogs, Dolphins, Dragons, Drivers, Editors, Employees, Engineers, Eskimos, Executives, Eyes, Families, Farmers, Fires, Fish, Flowers, Foxes, Garages, Gardeners, Generals, Goats, Governments, Grandparents, Grooms, Groupies, Guardians, Hands, Hens, *Hikes, Historians, Horses, Hosts, Hunters, Hurricanes, Insects, Instructors, Investors, Janitors, Jewelers, Joggers, Journalists, Judges, Keys, Kidnappers, Kids, Kittens, Knights, Knives, Landlords, Laws, Lawyers, Leaders, Leeches, Librarians, Lifeguards, Lions, Listeners, Locks, Locusts, Machines, Magazines, Magicians, Mailmen, Managers, Matadors, Mathematicians, Mayors, Mechanics, Men, Moles, Monkeys, Monks, Monsters, Morticians, Mosquitoes, Moths, Motorists, Movies, Museums, Musicians, Negotiators, Newlyweds, Newspapers, Nomads, Nuns, Nurses, Orchestras, Otters, Ovens, Pandas, Parents, Parrots, Patients, Patrolmen, Pediatricians, Pharmacists, Pickpockets, Pictures, Pills, Pilots, Pirates, Plumbers, Policemen, Politicians, Portraits, Postmen, Priests, Professors, Programs, Prosecutors, Protesters, Psychics, Psychologists, Publishers, Punters, Quarterbacks, Ranchers, Ranches, Rats, Readers, Realtors, Rebels, Referees, Reporters, Representatives, Reptiles, Restaurants, Retirees, Rivers, Rules, Rumors, Runners, Sailors, Salesmen, Satirists, Scientists, Scissors, Seamstresses, Secretaries, Senators, Shoppers, Shops, Smugglers, Snails, Snakes, Songs, Songwriters, Sopranos, Speakers, Spectators, Spies, Sprinters, Squirrels, Stars, Statisticians, Stores, Students, Submarines, Supervisors, Surgeons, Teachers, Teenagers, Telemarketers, Tenants, Theaters, Therapists, Thermometers, Thieves, Thunderstorms, Tigers, Tourists, Trains, Trees, Unions, Universities, Vegetarians, Veterinarians, Visitors, Waitresses, Warehouses, Weathermen, Witnesses*

Each of the nouns occurred in four conditions. The *neutral* condition contained only bare nouns. In the *positive quantifier* condition, the nouns were preceded by *many* or *nearly all*, and in the *negative quantifier* condition they were combined with *few* or *nearly no*. Each noun occurred with only one positive and one negative quantifier; the assignment of specific quantifiers to nouns was randomized. In the *negation* condition, nouns were followed by *don't*. The resulting phrases (e.g., *Reporters*…, *Reporters don't*…, *Many reporters*…, *Few reporters*…) were distributed across four lists in a counterbalanced manner such that each noun occurred once in each list. The order of stimuli within the lists was randomized.

Procedure

Participants were tested individually or in groups. They received booklets containing the stimuli and were instructed to complete the sentence fragments according to their expectation about a possible sentence continuation. They were encouraged to write simple and plausible sentences and to provide up to three answers per item only when they could easily think of more than one alternative. The instructions asked participants to use verbs denoting actions and to avoid descriptions as well as negations in their own answers. Examples of acceptable and unacceptable responses were provided. The completion of the task took between 1 and 2½ hours, with most subjects finishing within 1½ to 2 hours.

Data Analysis and Results

As most participants provided only one continuation for the vast majority of the items, all analyses were restricted to the first response each subject gave. At this point, only the first word of each response was used for the analysis.

Initially, responses that explicitly violated instructions were counted and removed from the data set. This affected all answers that started with forms of “be” or “have” and negations like “don’t”, “cannot”, “won’t” etc. A second, more reduced data set was constructed by retaining only verbs, but excluding all other lexical categories, namely adverbs and conjunctions. All analyses were conducted on both data sets. The data sets did not differ in the patterns of descriptive and inferential statistics derived from them. Therefore, only the results from the second, more restricted set will be reported.

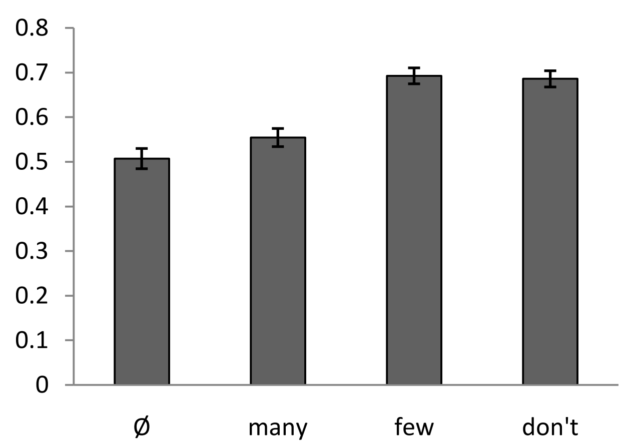
Table D-1. Condition-specific response statistics for the item *airplanes*. The table shows the stimulus in the four experimental conditions, the responses given by the participants, and the number of participants that gave that response. In addition, the number of valid responses (NVR) and the number of different responses (fan) are indicated along with the cloze probability of each response as well as the constraint of the stimulus item and the variability of responses in each condition.

Stimulus	Verb	Number of Mentions	Fan	NVR	Cloze	Constraint	Variability
Airplanes			3	20		.90	.15
(neutral)	fly	18			.90		
	carry	1			.05		
	employ	1			.05		
Airplanes don't			10	20		.35	.50
(negation)	fly	7			.35		
	crash	5			.25		
	allow	1			.05		
	debate	1			.05		
	fall	1			.05		
	float	1			.05		
	go	1			.05		
	swim	1			.05		
	travel	1			.05		
	walk	1			.05		
Nearly all airplanes			4	20		.75	.20
(positive quantifier)	fly	15			.75		
	can	2			.10		
	travel	2			.10		
	carry	1			.05		
Few airplanes			10	20		.35	.50
(negative quantifier)	crash	7			.35		
	fly	4			.20		
	float	2			.10		
	blow	1			.05		
	break	1			.05		
	explode	1			.05		
	go	1			.05		
	lack	1			.05		
	run	1			.05		
	take	1			.05		

Condition-Specific Measures

Initially, the same procedures were applied to each item separately for the four conditions: Responses were grouped to obtain a list of all verbs along with the number of subjects who provided that verb. The dominant response (DR) was identified as the verb that was given by the highest number of participants. When several verbs were tied as the most frequent ones, they were all considered DR.

Various descriptive measures were taken for each item in all four conditions: The *number of valid responses* (NVR) could vary between 0, if no subject provided a valid continuation, and 20, if all subjects gave a valid response. The *fan* is the number of different verbs; it could vary between 1, if all subjects gave the same single response, and 20, if 20 different valid responses were given. *Variability* was derived by dividing the fan by the NVR. A value of 1 indicates that all subjects gave different responses, a value of .05 means that all gave the same response. Figure D-1 shows that variability was higher in the negative than in the conditions, with the lowest variability in the neutral condition.



FigureD- 1. Mean variability in the neutral, positive and negative quantifier as well as the negation condition. Error bars indicate 95% confidence intervals.

The *cloze probability* (cloze) of a particular verb corresponds to the percentage of valid answers that were an instance of that verb. It was defined as the ratio of number of participants who gave that response to NVR. *Constraint* refers to the cloze of the DR of an item. Figure D-2 shows that the two positive conditions were more constraining than the negative conditions, with the strongest constraint in the neutral condition. If all subjects gave the same response, the value will be 1; if the response that occurred most frequently was given by 25% of subjects, it will be .25.

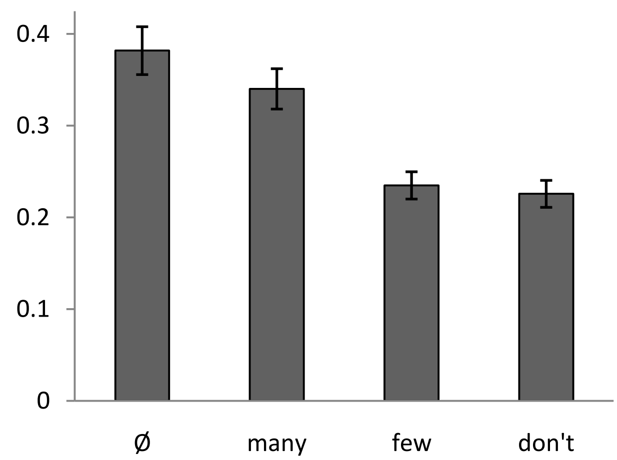


Figure D-2. Average constraint by conditions.
Error bars indicate 95% confidence intervals.

The *proportion of shared responses* is the percentage of all responses that also occurs in at least one other condition. For instance, in the example in Table D-1, the proportion of shared responses in the negative quantifier condition is .7 as 14 (7 x crash, 4 x *fly*, 2 x *float*, 1 x *go*) out of 20 responses occurred in at least one other condition (*fly* in all; *crash*, *float*, and *go* in the negation condition). Figure D-3 shows that compared to the negative conditions, a higher percentage of the responses given in the positive conditions re-occurred in other conditions.

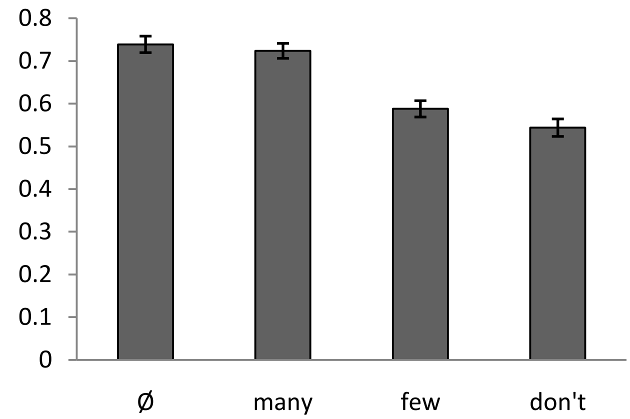


Figure D-3. Average proportion of shared responses in the four conditions. Error bars are 95% confidence intervals.

A weighted average of the *lexical frequency* of the responses (∑[frequency*cloze]) was computed for each item and condition. Lexical frequencies were taken from Kucera and Francis (1967). A higher average lexical frequency indicates that more common or generic verbs were used in the responses, while a lower value reflects responses that are likely more specific to the prompt. Figure D-4 shows that subjects gave more high-frequency responses (more generic words) in the negative compared to the positive conditions.

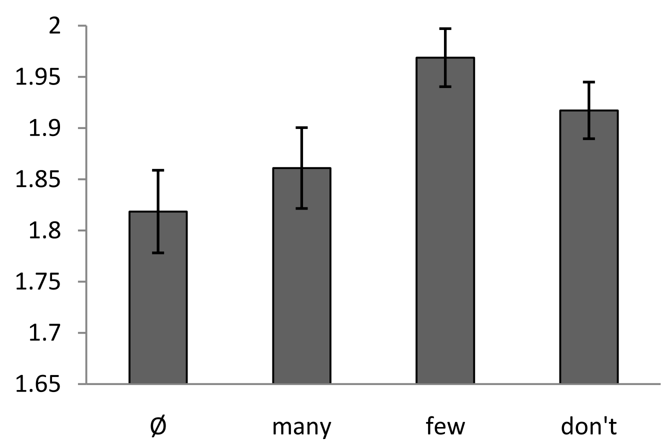


Figure D-4. Mean log lexical frequency for the four conditions. Error bars indicate 95% confidence intervals. Lexical frequencies are taken from Kucera and Francis (1967).

Measures of Relationship Between Conditions

In order to assess the relationships between the responses that were given in the different conditions, measures of the correlation and change of cloze probabilities as well as response overlap were taken on pairs of conditions.

Two kinds of correlations were computed: *Constraint correlation* is based on the constraints, i.e., the cloze of the DRs, that items achieved in the different conditions. Since the DR is not necessarily the same for an item in two conditions, the measure is item-, but not response-specific. *Cloze correlation*, on the other hand, relates the cloze of the response that is dominant in the first condition to the cloze of the same response in the second condition, irrespective of whether that response is the DR in the second condition as well.

An example may illustrate the difference between the two correlation types (*cf*. Table D-1): The constraint of the item *airplane* is .9 in the neutral condition and .35 in the negative quantifier condition. The pair of values used for the computation of the constraint correlation is therefore .9–.35. These numbers are, however, the cloze values of two different verbs: *Fly* is the DR in the neutral condition, while *crash* is the DR in the negative quantifier condition. The value pair for the neutral –negative quantifier cloze correlation therefore consists of .9 and .2, the cloze of *fly* in the two conditions, respectively. For the reverse cloze correlation (negative quantifier – neutral), the values are .35 and 0, the cloze of *crash* in the negative quantifier and neutral conditions, respectively. Thus, the order of conditions matters for cloze correlation; the measure is *asymmetric*. Values were computed for both orderings.

Table D-2 presents both measures. It shows that items with a high constraint in one positive condition also had a strong tendency to be very constraining in the other positive condition. The correlation between the two negative conditions was only moderate. Cloze in the positive conditions showed moderate correlations with cloze in the negative quantifier condition, but a very weak relationship with cloze in the negation condition. The asymmetric cloze correlations showed a similar pattern. However, there is a significant asymmetry involving the negation condition: The cloze of the DR in the negation condition is less predictive of the cloze of the same word in the positive conditions (.275 and .249 for neutral and positive quantifiers, respectively) than vice versa (.400 and .407, respectively).

Table D-2. Constraint and cloze correlations between the four conditions. For the asymmetric measure (cloze correlation), the condition whose dominant response (DR) was taken is listed horizontally; the vertical headings list the condition where the cloze for the word that was DR in the first condition was measured.

constraint	Ø	many	few	don't
Ø		.802	.395	.218
many	.802		.433	.169
few	.395	.433		.492
don't	.218	.169	.492	

cloze	Ø	many	few	don't
Ø		.803	.456	.275
many	.824		.475	.249
few	.507	.457		.501
don't	.400	.407	.525	

Table D-3. Change in cloze from the DR of the horizontally listed condition to the same word in vertically listed condition.

	Ø	many	few	don't
Ø		-.011	-.056	-.086
many	-.093		-.072	-.102
few	-.263	-.211		-.084
don't	-.278	-.239	-.084	

Cloze change is based on the same values as cloze correlation. It measures the difference between the cloze of the response that is dominant in the first condition to its cloze in the second condition. Cloze change varies between -1 and 1. Positive values indicate that the cloze decreases from the first to the second condition; negative values stand for an average increase in cloze. In the *airplanes* example, the change in the cloze of the DR *fly* from neutral to negative quantifier would be .65, the difference between .9 and .35. Table D-3 presents the results for this asymmetrical measure. It shows that if positive DRs recur in a negative conditions their cloze is considerably reduced (-.211 to -.278).

Cloze was used to compute the correlations as well as cloze change. By contrast, the actual verbs formed the basis for the measures of the extent to which responses are shared between pairs of conditions. The *proportion of common dominant responses* is the percentage of items that have the same DR in both of the two conditions of a pair. For this measure, the order of conditions in a pair is irrelevant, because a response has to fit the same criteria in both conditions, namely to be the DR. The direction of comparison does matter, however, for the *proportion of recurring dominant responses* which refers to the percentage of items for which the DR of the first condition simply figures among the responses given in the second condition (irrespective of whether it is the DR in the second condition or not). *Airplanes*, for example, has a does not have a common DR between the neutral and the negative quantifier condition. Yet, the DR *fly* of the neutral condition recurs in the negative quantifier condition, while the DR *crash* of the negative quantifier condition is not among the verbs produced in response to the neutral stimulus.

Table D-4 presents both measures. The left panel shows that the two positive conditions share a high proportion of DRs (.664), while there is only moderate consistency (.485) between the two negative conditions, and there are few common DRs between any pair of one positive and one negative condition (all <.35). The proportion of items whose DR recurs at all in the second condition, presented on the right, is overall higher than the percentage of items who have the same DR (shown on the left). Almost all DRs in the positive conditions re-occur in the other positive conditions (.962 and .939). A lower, but still very high proportion of negative DRs is also given in the other negative conditions (.828 and .821). As for the recurrence of DRs between positive and negative conditions, the proportions are overall lower (.508 to .729). In addition, the proportion of positive DRs that also occur in a negative condition is higher than that of negative DRs that occur in a positive condition. In both measures, there is a gradient from neutral to positive quantifier to negative quantifier to negation, with decreasing relatedness between more distant conditions.

Table D-4. Proportions of common and recurring dominant responses. For the proportion of recurring DRs, the condition in which the response is dominant is listed horizontally; the condition in which the cloze for the same word is measured is listed vertically.

Common	Ø	many	few	don't
Ø		.664	.321	.294
many	.664		.340	.248
few	.321	.340		.485
don't	.294	.248	.485	

recurring	Ø	many	few	don't
Ø		.939	.615	.508
many	.962		.656	.542
few	.729	.721		.821
don't	.676	.668	.828	

A measure of response overlap that focuses on all valid responses, i.e. each single answer, is the *proportion of recurring answers*. It indicates how many of the valid answers provided in response to the first condition of a pair also appear in the second condition. For each item, the number of recurring answers is divided by the NVR (of the first condition), and the results are averaged over items. In the *airplanes* example, the neutral and the negative quantifier condition overlap in only one response, the verb *fly*. Since *fly* was provided as an answer by eighteen participants, the percentage of answers from the 'neutral' condition that recur in the 'negative quantifier' condition is .90 (18 divided by 20). Starting with the negative quantifier condition, the proportion is .20, since *fly* was given as answer only four times in this condition.

Table D-5 presents the results for this measure. A relatively high proportion of answers are shared between the two positive conditions (.601 and .646). The percentage of responses that is shared between the two negative conditions (.438) is lower. It is similar to the percentage of positive responses that recur in the negative conditions (.420 to .483). The lower proportion of negative responses that recur in positive conditions (.272 to .351) indicates a similar asymmetry to that found in the other measures. This is of course expected since more different responses were given in the negative conditions than in the positive ones, so that there must be unique responses (i.e. non-recurring) in the negative conditions.

Table D-5. Proportion of individual answers of the horizontally listed condition that recur in the vertically listed condition.

	Ø	many	few	don't
Ø		.601	.319	.272
many	.646		.351	.294
few	.483	.462		.438
don't	.436	.420	.438	

Finally, the *semantic similarity* of responses was assessed via the correlated occurrence analogue to lexical semantics (COALS; Rohde, Gonnerman, & Plaut, 2004). COALS operationalizes semantic similarity as the tendency of words to occur in the same lexical contexts. For each item and condition pair, we computed the average similarity between the set of responses (weighted by their cloze) in one condition and the set of responses in the other condition. Table D-6 shows the average similarities. Responses in the two positive showed the strongest relationship. The similarity between the responses in the two negative conditions was second-highest. The similarities between pairs of positive and negative conditions showed the lowest values, and there was again a gradient of relatedness from neutral to negative.

Table D-6. Average semantic similarity as defined by COALS (Rohde et al., 2004) for all pairs of conditions.

	Ø	many	few	don't
Ø		.865	.698	.676
many	.865		.716	.682
few	.698	.716		.772
don't	.676	.682	.772	

Overall, the positive conditions showed more consistent responses that also tended to re-occur in other conditions, probably because these responses were most closely associated with the stimulus nouns. In the negative conditions, subjects gave more variable and more generic responses, probably because they perceived the negative prompts to be less constraining.

REFERENCES

Altmann, G. T. M., & Kamide, Y. (1999). Incremental interpretation at verbs: Restricting the domain of subsequent reference. *Cognition, 73*, 247-264.

Altmann, G. T. M., & Kamide, Y. (2007). The real-time mediation of visual attention by language and world knowledge: Linking anticipatory (and other) eye movements to linguistic processing. *Journal of Memory & Language, 57*, 502-518.

Aristotle. (1961-1966). *Works*. London: Oxford University Press.

Bentin, S., McCarthy, G., & Wood, C. C. (1985). Event-related potentials associates with semantic priming. *Electroencephalography and Clinical Neurophysiology, 60*, 343-355.

Bles, M., Alink, A., & Jansma, B. M. (2007). Neural aspects of cohort-size reduction. *Brain Research, 1150*, 143-154.

Bloom, L. (1970). *Language development: form and function in emerging grammars*. Cambridge, MA: MIT Press.

Bloom, L. (1991). On the acquisition of negation in Tamil and English. *Journal of Child Language, 18*, 715-716.

Bock, J. K. (1986). Syntactic persistence in language production. *Cognitive Psychology, 18*, 355-387.

Branigan, H. P., Pickering, M. J., & McLean, J. F. (2005). Priming prepositional-phrase attachment during comprehension. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 31*, 468-481.

Bretz, F., Hothorn, T., & Westfall, P. H. (2002). On multiple comparisons in R [Electronic Version]. *R News*, 2(3), 14-17. Retrieved 5/7/2007 from http://cran.r-project.org/doc/Rnews/Rnews_2002-3.pdf.

Brown, P., & Levinson, S. C. (1987). *Politeness: Some universals in language use*. Cambridge [UK], New York: Cambridge University Press.

Brown, R. (1973). *A first language*. Cambridge: Harvard University Press.

Bruner, J. S., Goodnow, J. J., & Austin, G. A. (1956). *A study of thinking*. New York: Wiley.

Caitlin, J., & Jones, N. K. (1976). Verifying affirmative and negative sentences. *Psychological Review, 83*, 497-501.

Carpenter, P. A., & Just, M. A. (1975). Sentence comprehension: A psycholinguistic model of verification. *Psychological Review, 82*, 45-76.

Carpenter, P. A., Just, M. A., Keller, T. A., Eddy, W. F., & Thulborn, K. R. (1999). Time course of fMRI-activation in language and spatial networks during sentence comprehension. *NeuroImage, 10*, 216-224.

Chomsky, N. (1957). *Syntactic structures*. The Hague: Mouton.

Clark, H. H. (1976). *Semantics and comprehension*. The Hague: Mouton.

Clark, H. H., & Card, S. K. (1969). Role of semantics in remembering comparative sentences. *Journal of Experimental Psychology, 82*, 545-553.

Clark, H. H., & Chase, W. G. (1972). On the process of comparing sentences against pictures. *Cognitive Psychology, 3*, 472-517.

Colston, H. L. (1999). "Not good" is "bad," but "not bad" is not "good": An analysis of three accounts of negation asymmetry. *Discourse Processes, 28*, 237-256.

Colston, H. L., & O'Brien, J. (2000). Contrast and pragmatics in figurative language: Anything understatement can do, irony can do better. *Journal of Pragmatics, 32*, 1557-1583.

Cornish, E. R. (1971). Pragmatic aspects of negation in sentence evaluation and completion tasks. *British Journal of Psychology, 62*, 505-511.

Cornish, E. R., & Wason, P. C. (1970). The recall of affirmative and negative sentences in an incidental learning task. *Quarterly Journal of Experimental Psychology, 22*, 109-114.

Cowan, N., & Morey, C. C. (2007). How can dual-task working memory retention limits be investigated? *Psychological Science, 18*, 686-688.

Crocker, M. W., & Brants, T. (2000). Wide-coverage probabilistic sentence processing. *Journal of Psycholinguistic Research, 29*, 647-669.

Dahl, Ö. (1979). Typology of sentence negation. *Linguistics, 17*, 79-106.

De Mey, M. (1971). Negation and attention. *Communication & Cognition, 4*, 187-197.

de Villiers, J. G., & Flusberg, H. B. T. (1975). Some facts one simply cannot deny. *Journal of Child Language, 2*, 279-286.

DeLong, K. A., Urbach, T. P., & Kutas, M. (2005). Probabilistic word pre-activation during language comprehension inferred from electrical brain activity. *Nature Neuroscience, 8*, 1117-1121.

Donaldson, M. (1970). Developmental aspects of performances with negatives. In G. B. Flores d'Arcais & W. J. M. Levelt (Eds.), *Advances in psycholinguistics*. Amsterdam: North-Holland.

Donchin, E., & Coles, M. G. H. (1988). Is the P300 a manifestation of context updating? *Behavioral and Brain Sciences, 11*, 357-374.

Duffy, S. A., Morris, R. K., & Rayner, K. (1988). Lexical ambiguity and fixation times in reading. *Journal of Memory & Language, 27*, 429-446.

Duncan-Johnson, C. C., & Donchin, E. (1977). On quantifying surprise: The variation of event-related potentials with subjective probability. *Psychophysiology, 14*, 456-467.

Eifermann, R. R. (1961). Negation: a linguistic variable. *Acta Psychologica, 18*, 258-273.

Engelbretsen, G. (1981a). *Logical Negation*. Assen, Netherlands: Van Gorcum.

Engelbretsen, G. (1981b). *Three Logicians: Aristotle, Leibniz, and Sommers and the Syllogistic*. Assen, Netherlands: Van Gorcum.

Evans, J. S. B. T. (1972). Reasoning with negatives. *British Journal of Psychology, 63*, 213-219.

Evans, J. S. B. T. (1998). Matching bias in conditional reasoning: Do we understand it after 25 years? *Thinking & Reasoning, 4*, 45-82.

Fauconnier, G. (Ed.). (1985). *Mental Spaces*. Cambridge: Cambridge University Press.

Faustmann, A., Murdoch, B. E., Finnigan, S. P., & Copland, D. A. (2005). Event-related brain potentials elicited by semantic and syntactic anomalies during auditory sentence processing. *Journal of the American Academy of Audiology, 16*, 708-725.

Federmeier, K., Wlotko, E. W., De Ochoa-Ewald, E., & Kutas, M. (2007). Multiple effects of sentential constraint on word processing. *Brain Research, 1146*, 75-84.

Fedorenko, E., & Gibson, T. (2005, April). *Syntactic priming in comprehension*. Poster presented at the 18th Annual CUNY Sentence Processing Conference, Tucson, AZ.

Felser, C., Clahsen, H., & Münte, T. F. (2003). Storage and integration in the processing of filler-gap dependencies. *Brain and Language, 87*.

Fiebach, C. J., Schlesewsky, M., & Friederici, A. D. (2001). Syntactic working memory and the establishment of filler-gap dependencies: Insights from ERPs and fMRI. *Journal of Psycholinguistic Research, 30*, 321-338.

Fillmore, C. (1985). Frames and the semantics of understanding. *Quaderni de Semantica, 6*, 222-254.

Fischler, I., Bloom, P. A., Childers, D. G., Arroyo, A. A., & Perry, N. W. J. (1984). Brain potentials during sentence verification: late negativity and long-term memory strength. *Neuropsychologia, 22*, 559-568.

Fischler, I., Bloom, P. A., Childers, D. G., Roucos, S. E., & Perry, N. W. J. (1983). Brain potentials related to stages of sentence verification. *Psychophysiology, 20*, 400-409.

Fischler, I., Childers, D. G., Achariyapaopan, T., & Perry, N. W. J. (1985). Brain potentials during sentence verification: automatic aspects of comprehension. *Biological Psychology, 21*, 83-105.

Fraser, B. (1980). Conversational mitigation. *Journal of Pragmatics, 4*, 341-350.

Frege, F. L. G. (1884). *Grundlagen der Arithmetik: Eine logisch-mathematische Untersuchung über den Begriff der Zahl*. Breslau: Verlag von Wilhelm Koebner.

Frege, F. L. G. (1919). Die Verneinung. *Beiträge zur Philosophie des deutschen Idealismus, I*, 143-157.

Friederici, A. D., Pfeifer, E., & Hahne, A. (1993). Event-related brain potentials during natural speech processing: effects of semantic, morphological and syntactic violations. *Cognitive Brain Research, 1*, 183-192.

Gernsbacher, M. A. (1990). *Language comprehension as structure building*. Hillsdale NJ: Erlbaum.

Giora, R. (1995). On irony and negation. *Discourse Processes, 19*, 239-264.

Giora, R. (2003). *On our mind: salience, context, and figurative language*. New York: Oxford University Press.

Giora, R. (2006). Anything negatives can do affirmatives can do just as well, except for some metaphors. *Journal of Pragmatics, 39*, 981-1014.

Giora, R. (2007). "A good Arab is not a dead Arab - a racist incitement": On the accessibility of negated concepts. In I. Kecskes & L. R. Horn (Eds.), *Explorations in Pragmatics: Linguistic, Cognitive, and Intercultural Aspects* (pp. 129-162). Berlin: Mouton de Gruyter.

Giora, R., Balaban, N., Fein, O., & Alkabets, I. (2004). Negation as positivity in disguise. In H. L. Colston & A. Katz (Eds.), *Figurative language comprehension: Social and cultural influences* (pp. 233-258). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Giora, R., Fein, O., Aschkenazi, K., & Alkabets-Zlozover, I. (2007). Negation in context: A functional approach to suppression. *Discourse Processes, 43*, 153-172.

Giora, R., Fein, O., Ganzi, J., Levi, N. A., & Sabah, H. (2005). On Negation as Mitigation: The Case of Negative Irony. *Discourse Processes, 39*, 81-100.

Givón, T. (1978). Negation in language: Pragmatics, function, ontology. In P. Cole (Ed.), *Pragmatics*. New York: Academic Press.

Givón, T. (1979). *On understanding grammar*. New York: Academic Press.

Givón, T. (1984). *Syntax: A functional-typological introduction* (Vol. I). Amsterdam, Philadelphia: John Benjamins.

Givón, T. (1989). *Mind, code and context: Essays in Pragmatics*. Hillsdale, NJ: Erlbaum.

Givón, T. (1993). *English grammar: a function-based introduction* (Vol. I). Amsterdam, Philadelphia: John Benjamins.

Glass, A. L., Holyoak, K. J., & O'Dell, C. (1974). Production frequency and the verification of quantified statements. *Journal of Verbal Learning & Verbal Behavior, 13*, 237-254.

Glenberg, A. M., Meyer, M., & Lindem, K. (1987). Mental models contribute to foregrounding during text comprehension. *Journal of Memory & Language, 26*, 69-83.

Glenberg, A. M., Robertson, D. A., Jansen, J. L., & Johnson-Glenberg, M. C. (1999). Not propositions. *journal of Cognitive Systems Research, 1*.

Goldman-Eisler, F., & Cohen, M. (1970). Is N, P, and PN difficulty a valid criterion of transformational operations? *Journal of Verbal Learning & Verbal Behavior, 9*, 161-166.

Gough, P. B. (1965). Grammatical transformations and speed of understanding. *Journal of Verbal Learning & Verbal Behavior, 4*, 107-111.

Graesser, A. C., Millis, K. K., & Zwaan, R. A. (1997). Discourse comprehension. *Annual Review of Psychology, 48*, 163-189.

Graesser, A. C., Singer, M., & Trabasso, T. (1994). Constructing inferences during narrative text comprehension. *Psychological Review, 101*, 371-395.

Grant, S. J., Malaviya, P., & Sternthal, B. (2004). The Influence of Negation on Product Evaluations. *Journal of Consumer Research, 31*, 583-591.

Greenberg, J. H. (1966). *Language universals*. The Hague: Mouton.

Greene, J. M. (1970). The semantic function of negatives and passives. *British Journal of Psychology, 6*, 17-22.

Greene, J. M., & Wason, P. C. (1970). Negation: A rejoinder to Wales and Grieve. *Perception & Psychophysics, 8*, 238-239.

Greenhouse, S. W., & Geisser, S. (1959). On methods in the analysis of profile data. *Psychometrika, 24*, 95-112.

Grice, H. P. (1975). Logic and conversation. In P. Cole & J. Morgan (Eds.), *Speech acts* (pp. 41-58). New York: Academic Press.

Hagoort, P., & Brown, C. M. (2000). ERP effects of listening to speech: semantic ERP effects. *Neuropsychologia, 11*, 1518-1530.

Hasson, U., & Glucksberg, S. (2006). Does understanding negation entail affirmation? An examination of negated metaphors. *Journal of Pragmatics, 38*, 1015-1032.

Hidalgo Downing, L. (2000). *Negation, text worlds, and discourse: The pragmatics of fiction*. Stamford, CT: Ablex.

Hochberg, Y. (1988). A sharper Bonferroni procedure for multiple tests of significance. *Biometrika, 75*, 800-802.

Horn, L. R. (1978). Lexical incororation, implicature, and the Least Effort Hypothesis. In D. Farkas, W. M. Jacobsen & K. W. Todrys (Eds.), *Papers from the parasession on the lexicon*. Chicago: Chicago Linguistic Society.

Horn, L. R. (1984). Toward a taxonomy for pragmatic inference: Q-based and R-based implicature. In D. Schiffrin (Ed.), *Meaning, form, and use in context: Linguistic applications (GURT '84)* (pp. 11-42). Washington: Georgetown University Press.

Horn, L. R. (1989). *A Natural History of Negation*. Chicago: University of Chicago Press.

Howard, J. H. (1975). The attentional demands of negation in a memory-scanning task. *Memory & Cognition, 3*, 319-324.

Jackendoff, R. (1972). *Semantic interpretation in generative grammar*. Cambridge, MA: MIT Press.

Jakobson, R. (1932). Zur Struktur des russischen Verbums. In *Charesteria Guilelmo Mathesio quinquagenario a discipulis et Circuli Linguistici Pragensis sodalibus oblata* (pp. 74-84). Prague: Cercle Linguistique de Prague.

Jakobson, R. (1939). Signe zéro. In *Mélanges de linguistique offerts à Charles Bally* (pp. 143-152). Geneva: Georg et Cie.

Jespersen, O. (1917). *Negation in English and other languages*. Copenhagen: A. F. Høst.

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

Kamide, Y., Altmann, G. T. M., & Haywood, S. L. (2003). The time-course of prediction in incremental sentence processing: Evidence from anticipatory eye movements. *Journal of Memory & Language, 49*, 133-156.

Kamide, Y., Scheepers, C., & Altmann, G. T. M. (2003). Integration of syntactic and semantic information in predictive processing: Cross-linguistic evidence from German and English. *Journal of Psycholinguistic Research, 32*, 37-55.

Katz, J. J., & Postal, P. M. (1964). *An integrated theory of linguistic description*. Cambridge, MA: MIT Press.

Kaup, B. (1997). The processing of negatives during discourse comprehension. In M. G. Shafto & P. Langley (Eds.), *Proceedings of the Nineteenth Conference of the Cognitive Science Society* (pp. 370-375). Mahwah, NJ: Erlbaum.

Kaup, B. (2001). Negation and its impact on the accessibility of text information. *Memory & Cognition, 29*, 960-967.

Kaup, B. (2006). What psycholinguistic negation research tells us about the nature of the working memory representations utilized in language comprehension. In H. Pishwa (Ed.), *Language and Memory: Aspects of Knowledge Representation* (pp. 313-355). Berlin: Mouton de Gruyter.

Kaup, B., Lüdtke, J., & Burkert, M. (2006, August). *Effects of polarity in language comprehension: Is negation really an availability reducing operator?* Poster presented at the AMLaP Conference 2006, University Nijmegen, The Netherlands.

Kaup, B., Lüdtke, J., & Zwaan, R. A. (2005). Effects of negation, truth value, and delay on picture recognition after reading affirmative and negative sentences. In B. G. Bara, L. Barsalou & M. Bucciarelli (Eds.), *Proceedings of the 27th Annual Conference of the Cognitive Science Society* (pp. 1114-1119). Mahwah, NJ: Lawrence Erlbaum.

Kaup, B., Lüdtke, J., & Zwaan, R. A. (2006). Processing negated sentences with contradictory predicates: Is that door that is not open mentally closed? *Journal of Pragmatics, 38*, 1033-1050.

Kaup, B., Yaxley, R. H., Madden, C. J., Zwaan, R. A., & Lüdtke, J. (2007). Experiential simulations of negated text information. *Quarterly Journal of Experimental Psychology, 60*, 976-990.

Kaup, B., & Zwaan, R. A. (2003). Effects of negation and situational presence on the accessibility of text information. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 29*, 439-446.

Kaup, B., Zwaan, R. A., & Lüdtke, J. (2007). The experiential view of language comprehension: How is negation represented? In F. Schmalhofer & C. A. Perfetti (Eds.), *Higher level language processes in the brain: Inference and comprehension processes* (pp. 255-288). Mahwah, NJ: Lawrence Erlbaum.

Keefe, D. E., & McDaniel, M. A. (1993). The time course and durability of predictive inferences. *Journal of Memory & Language, 32*, 446-463.

Kim, K. (1985). Development of the concept of truth-functional negation. *Developmental Psychology, 21*, 462-472.

King, J. W., & Kutas, M. (1995). Who did what when? Using word- and clause-level ERPs to monitor working memory usage in reading. *Journal of Cognitive Neuroscience, 7*, 376-395.

Klima, E. S. (1964). Negation in English. In J. A. Fodor & J. J. Katz (Eds.), *The structure of language*. Englewood Cliffs, NJ: Prentice-Hall.

Klima, E. S., & Bellugi, U. (1966). Syntactic regularities in the speech of children. In R. Lyons & R. J. Wales (Eds.), *Psycholinguistic papers*. Edinburgh: Edinburgh University Press.

Kok, A. (2001). On the utility of P3 amplitude as a measure of processing capacity. *Psychophysiology, 38*, 557-577.

Kolk, H. H. J., Chwilla, D. J., van Herten, M., & Oor, P. J. W. (2003). Structure and limited capacity in verbal working memory: A study with event-related potentials. *Brain and Language, 85*, 1-36.

Kounios, J., & Holcomb, P. J. (1992). Structure and process in semantic memory: Evidence from event-related brain potentials and reaction times. *Journal of Experimental Psychology: General, 121*, 459-479.

Kucera, H., & Francis, W. N. (1967). *Computational analysis of present-day American English*. Providence, RI: Brown University Press.

Kuperberg, G. R., Holcomb, P. J., Sitnikova, T., Greve, D., Dale, A. M., & Caplan, D. (2003). Distinct patterns of neural modulation during the processing of conceptual and syntactic anomalies. *Journal of Cognitive Neuroscience, 15*.

Kutas, M., Federmeier, K., Staab, J., & Kluender, R. (2007). Language. In J. T. Cacioppo, L. G. Tassinary & G. G. Berntson (Eds.), *Handbook of Psychophysiology* (3rd ed., pp. 555-580). New York: Cambridge University Press.

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: brain potentials reflect semantic incongruity. *Science, 207*, 203-205.

Kutas, M., & Hillyard, S. A. (1984). Brain potentials during reading reflect word expectancy and semantic association. *Nature, 307*, 161-163.

Langacker, R. W. (1991). *Foundations of cognitive grammar: Vol. II, descriptive application*. Palo Alto: Stanford University Press.

Lea, R. B. (1995). On-line evidence for elaborative logical inferences in text. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 21*, 1469-1482.

Lea, R. B., & Mulligan, E. J. (2002). The effect of negation on deductive inferences. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 28*, 303-317.

Leech, G. N. (1981). Pragmatics and conversational rhetoric. In H. Parret, M. Sbisa & J. Verschueren (Eds.), *Possibilities and limitations of pragmatics*. Amsterdam: Benjamins.

Leech, G. N. (1983). *Principles of pragmatics*. London: Longman.

Luck, S. J., & Hillyard, S. A. (1994). Electrophysiological correlates of feature analysis during visual search. *Psychophysiology, 31*, 291-308.

Lüdtke, J., Friedrich, C. K., De Filippis, M., & Kaup, B. (2005, November). *ERP correlates of negation in a sentence-picture verification paradigm*. Poster presented at the 45th Annual Meeting of the Psychonomic Society, Toronto, Canada.

Lüdtke, J., & Kaup, B. (2006). Context effects when reading negative and affirmative sentences. In R. Sun (Ed.), *Proceedings of the 28th Annual Conference of the Cognitive Science Society* (pp. 1735-1740). Mahwah, NJ: Lawrence Erlbaum.

Luedtke, J., De Filippis, M., Friedrich, C. K., & Kaup, B. (2005, November). *ERP correlates of negation in a sentence-picture verification paradigm*. Poster presented at the 45th Annual Meeting of the Psychonomic Society, Toronto, Canada.

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

MacLeod, C. M., Hunt, E. B., & Mathews, N. N. (1978). Individual differences in the verification of sentence-picture relationships. *Journal of Verbal Learning & Verbal Behavior, 17*, 493-507.

Mathews, N. N., Hunt, E. B., & MacLeod, C. M. (1980). Strategy choice and strategy training in sentence-picture verification. *Journal of Verbal Learning & Verbal Behavior, 19*, 531-548.

Mayo, R., Schul, Y., & Burnstein, E. (2004). "I am not guilty" vs "I am innocent": Successful negation may depend on the schema used for its encoding. *Journal of Experimental Social Psychology, 40*, 433-449.

McKoon, G., & Ratcliff, R. (1992). Inference during reading. *Psychological Review, 99*, 440-466.

McMahon, L. E. (1963). *Grammatical analysis as part of understanding a sentence*. Unpublished doctoral dissertation, Harvard University.

Mehler, J. (1963). Some effects of grammatical transformations on the recall of English sentences. *Journal of Verbal Learning & Verbal Behavior, 2*.

Melara, R. D., Rao, A., & Tong, Y. (2002). The duality of selection: Excitatory and inhibitory processes in auditory selective attention. *Journal of Experimental Psychology: Human Perception and Performance, 28*, 279-306.

Miller, G. A. (1962). Some psychological studies of grammar. *American Psychologist, 17*, 748-762.

Miller, G. A., & McKean, K. O. (1968). A chronometric study of some relations between sentences. In R. C. Oldfield & J. C. Marshall (Eds.), *Language*. Baltimore, MD: Penguin Books.

Minsky, M. L. (1975). A framework for representing knowledge. In P. Winston (Ed.), *The psychology of computer vision* (pp. 211-227). New York: McGraw-Hill.

Moser, M. G. (1992). *The negation relation: Semantic and pragmatic aspects of a relational analysis of sentential negation.* Unpublished Dissertation, University of Pennsylvania, Philadelphia.

Moxey, L. M., & Sanford, A. J. (1993). *Communicating quantities*. Hove, UK: Erlbaum.

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

Münte, T. F., Heinze, H.-J., Matzke, M., Wieringa, B. M., & Johannes, S. (1998). Brain potentials and syntactic violations revisited: no evidence for specificity of the syntactic positive shift. *Neuropsychologia, 36*, 217-226.

Münte, T. F., Schlitz, K., & Kutas, M. (1998). When temporal terms belie conceptual order: an electrophysiological analysis. *Nature, 395*, 71-73.

Oaksford, M. (2002). Contrast classes and matching bias as explanations of the effects of negation on conditional reasoning. *Thinking & Reasoning, 8*, 135-151.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia, 9*, 97-113.

Osterhout, L., & Holcomb, P. J. (1992). Event-related potentials elicited by syntactic anomaly. *Journal of Memory & Language, 31*, 785-806.

Otten, M., Nieuwland, M. S., & Van Berkum, J. J. A. (2007). Great expectations: specific lexical anticipation influences the processing of spoken language. *BMC Neuroscience, 8*, 89.

Pagano, A. (1994). Negatives in written text. In M. Coulthard (Ed.), *Advances in written text analysis* (pp. 250-265). London, New York: Routledge.

Pashler, H. (1994). Dual-task interference in simple tasks: Data and theory. *Psychological Bulletin, 116*, 220-244.

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

Pea, R. D. (1980a). The development of negation in early child language. In D. R. Olson (Ed.), *The social foundations of language and thought*. New York: Norton.

Pea, R. D. (1980b). Logic in early child language. *Annals of the New York Academy of Sciences, 345*, 27-43.

Phillips, C., Kazanina, N., & Abada, S. H. (2005). ERP effects of the processing of syntactic long-distance dependencies. *Cognitive Brain Research, 22*, 407-428.

Pickering, M. J., & Traxler, M. J. (2004, March). *Grammatical repetition and garden-path effects*. Poster presented at the 17th annual CUNY Conference on Human Sentence Processing, Maryland, MD.

Rayner, K., & Sereno, S. C. (1994). Eye movements in reading. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 57-81). New York: Academic Press.

Roberts, M. J., Wood, D. J., & Gilmore, D. J. (1994). The sentence-picture verification task: Methodological and theoretical difficulties. *British Journal of Psychology, 85*, 413-432.

Rohde, D. L. T., Gonnerman, L. M., & Plaut, D. C. (2004). An improved method for deriving word meaning from lexical co-occurence. Unpublished manuscritpt. Retrieved 12/05/2007 from http://dlt4.mit.edu/~dr/COALS/Coals.pdf

Rumelhart, D. E. (1980). Schemata: The building blocks of cognition. In R. J. Spiro, B. Bruce & W. Brewer (Eds.), *Theoretical issues in reading comprehension* (pp. 33-58). Hillsdale, NJ: Erlbaum.

Salmon, N., & Pratt, H. (2002). A comparison of sentence- and discourse-level semantic processing: An ERP study. *Brain and Language, 83*, 367-383.

Sanford, A. J., & Garrod, S. C. (1989). What, when and how? Questions of immediacy in anaphoric reference resolution. *Language and Cognitive Processes, 4*, 235-262.

Sanford, A. J., & Moxey, L. M. (2004). Exploring quantifiers: Pragmatics meets the psychology of comprehension. In I. A. Noveck & D. Sperber (Eds.), *Experimental Pragmatics* (pp. 116-137). Basingstoke, Hampshire ; New York: Palgrave Macmillan.

Sanford, A. J., Moxey, L. M., & Paterson, K. B. (1996). Attentional focusing with quantifiers in production and comprehension. *Memory & Cognition, 24*, 144-155.

Sanford, A. J., Williams, C., & Fay, N. (2001). When being included is being excluded: A note on complement set focus and the inclusion relation. *Memory & Cognition, 29*, 1096-1101.

Schank, R. C., & Abelson. (1977). *Scripts, plans, goals and understanding*. Hillsdale, NJ: Erlbaum.

Schmalhofer, F., & Glavanov, D. (1986). Three components of understanding a programmer's manual: verbatim, propositional, and situational representations. *Journal of Memory & Language, 25*, 279-294.

Shannon, B. (1981). What is in the frame? - Linguistic indicators. *Journal of Pragmatics, 5*, 35-44.

Sherman, M. A. (1976). Adjectival negation and the comprehension of multiply negated sentences. *Journal of Verbal Learning & Verbal Behavior, 15*, 143-157.

Shoben, E. (1978). Choosing a model of sentence-picture comparisons: A reply to Catlin and Jones. *Psychological Review, 85*, 131-137.

Singer, M. (1977). A constituent comparison model of a picture-first verification task. *Memory & Cognition, 5*, 269-272.

Slobin, D. I. (1964). *Grammatical transformations in childhood and adulthood.* Unpublished doctoral dissertation, Harvard University.

Slobin, D. I. (1966). Grammatical transformations and sentence comprehension in childhood and adulthood. *Journal of Verbal Learning & Verbal Behavior, 5*.

Sperber, D., & Wilson, D. (1986). *Relevance: Communication and cognition*. Cambridge, MA: Harvard University Press.

Stanovich, K. E., & Cunningham, A. (1992). Studying the consequences of literacy within a literate society: the cognitive correlates of print exposure. *Memory & Cognition, 20*, 51-68.

Stanovich, K. E., & Cunningham, A. (1993). Where does knowledge come from? Specific associations between print exposure and information acquisition. *Journal of Educational Psychology, 85*, 211-229.

Stanovich, K. E., West, R. F., & Harrison, M. (1995). Knowledge growth and maintenance across the life span: The role of print exposure. *Developmental Psychology, 31*, 811-826.

Sternberg, S. (1969). High-speed scanning in human memory. *Science, 153*, 652-654.

Strawson, P. F. (1952). *Introduction to logical theory*. London: Methuen.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 28*, 643-662.

Tanenhaus, M. K., Carroll, J. M., & Bever, T. G. (1976). Sentence-picture verification models as theories of sentence comprehension: A critique of Carpenter and Just. *Psychological Review, 83*, 310-317.

Taylor, W. L. (1953). Cloze procedure: A new tool for measuring readability. *Journalism Quarterly, 30*, 415-433.

Thothathiri, M., & Snedeker, J. (submitted). Give and take: syntactic priming during spoken language comprehension.

Tombu, M., & Joelicoeur, P. (2003). A central capacity sharing model of dual-task performance. *Journal of Experimental Psychology: Human Perception and Performance, 29*, 3-18.

Tottie, G. (1982). Where do negative sentences come from? *Studia Linguistica, 36*, 88-105.

Tottie, G. (1991). *Negation in English speech and writing: A study in variation*. San Diego: Academic Press.

Trabasso, T., Rollins, H., & Shaughnessy, E. (1971). Storage and verification stages in processing concepts. *Cognitive Psychology, 2*, 239-289.

Trubetzkoy, N. (1931). Die phonologischen Systeme. *Travaux du Cercle Linguistique de Prague, 6*, 96-116.

Trubetzkoy, N. (1939). Grundzüge der Phonologie. *Travaux du Cercle Linguistique de Prague, 7*, 1-271.

Vaidyanathan, R. (1991). Development of forms and functions of negation in the early stages of language acquisition: A study in Tamil. *Journal of Child Language, 18*, 51-66.

van Berkum, J. J. A., Brown, C. M., Zwitserlood, P., Kooijman, V., & Hagoort, P. (2005). Anticipating upcoming words in discourse: Evidence fromERPs and reading times. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 31*, 443-367.

van Berkum, J. J. A., Hagoort, P., & Brown, C. M. (1999). Semantic integration in sentences and discourse: evidence from the N400. *Journal of Cognitive Neuroscience, 11*, 657-671.

Van Berkum, J. J. A., Koornneef, A. W., Otten, M., & Nieuwland, M. S. (2007). Establishing reference in language comprehension: An electrophysiological perspective. *Brain Research, 1146*, 158-171.

van Berkum, J. J. A., Zwitserlood, P., Hagoort, P., & Brown, C. M. (2003). When and how do listeners relate a sentence to the wider discourse? Evidence from the N400 effect. *Cognitive Brain Research, 17*, 701-718.

van Dijk, T. A., & Kintsch, W. (1983). *Strategies of discourse comprehension*. New York: Academic Press.

Van Petten, C., Weckerly, J., McIsaac, H. K., & Kutas, M. (1997). Working memory capacity dissociates lexical and sentential context effects. *Psychological Science, 8*, 238-242.

Van Selst, M., & Jolicoeur, P. (1994). A solution to the effect of sample size on outlier elimination. *Quarterly Journal of Experimental Psychology, 47A*, 631-650.

Wales, R. J., & Grieve, R. (1969). What is so difficult about negation? *Perception & Psychophysics, 6*, 327-332.

Wason, P. C. (1959). The processing of positive and negative information. *Quarterly Journal of Experimental Psychology, 11*, 92-107.

Wason, P. C. (1961). Response to affirmative and negative binary statements. *British Journal of Psychology, 52*, 133-142.

Wason, P. C. (1965). The contexts of plausible denial. *Journal of Verbal Learning & Verbal Behavior, 4*, 7-11.

Wason, P. C. (1971). In real life negatives are false. *Communication & Cognition, 4*, 239-253.

Wason, P. C., & Jones, S. (1963). Negatives: Denotation and connotation. *British Journal of Psychology, 54*, 299-307.

Westfall, P. H., Tobias, R. D., Rom, D., Wolfinger, R. D., & Hochberg, Y. (1999). *Multiple comparisons and multiple tests using the SAS system*. Cary, NC: SAS Institute Inc.

Wicha, N. Y. Y., Moreno, E. M., & Kutas, M. (2004). Anticipating words and their gender: An event-related brain potential study of semantic integration, gender expectancy, and gender agreement in Spanish sentence reading. *Journal of Cognitive Neuroscience, 16*, 1271-1288.

Wilson, D., & Sperber, D. (2004). Relevance Theory. In L. R. Horn & G. Ward (Eds.), *Handbook of Pragmatics* (pp. 607-632). Oxford: Blackwell.

Young, R., & Chase, W. G. (1971). *Additive stages in the comparison of sentences and pictures*. Paper presented at Midwestern Psychological Association meetings, Chicago (April).

Zwaan, R. A. (2004). The immersed experiencer: Toward an embodied theory of language comprehension. In B. H. Ross (Ed.), *The Psychology of Language and Motivation* (Vol. 44, pp. 35-62). New York: Academic Press.

Zwaan, R. A., & Radvansky, G. A. (1998). Situation models in language comprehension and memory. *Psychological Bulletin, 123*, 162-185.