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Experimental Work in Presupposition and Presupposition Projection

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Abstract

Recent years have seen a surge of experimental approaches to the study of natural language meaning, both to obtain solid data on subtle phenomena that are hard to assess through introspection and to understand how abstract characterizations of linguistic knowledge relate to real-time cognitive processes in language comprehension. This article reviews research in one of the most recent areas to see extensive experimental investigations, namely presupposition and presupposition projection. Presuppositions are at the very nexus of linguistically encoded content and contextual information, as they relate directly to the discourse context but also interact in intricate ways with their intra-sentential linguistic environment. They are thus extremely suitable for investigations of the interplay of linguistic and more domain-general processes in language comprehension, as well as for experimental investigations of subtle theoretical phenomena.

1. INTRODUCTION

Given its origins in philosophy and logic, the study of linguistic meaning has traditionally focused on developing formal accounts of basic empirical phenomena that are easily accessible through intuitions. However, recent years have seen a surge of more systematic empirical approaches to the overall enterprise, both to obtain solid data on subtle phenomena that are hard to assess through introspection and to understand how abstract characterizations of linguistic knowledge relate to real-time cognitive processes in language comprehension. This article reviews research in one of the most recent areas to see extensive experimental investigations, namely presupposition and presupposition projection. Presuppositions are at the very nexus of linguistically encoded content and contextual information, as they relate directly to the discourse context but also interact in intricate ways with their intra-sentential linguistic environment. More specifically, presuppositions convey information that is typically assumed to already be taken for granted by the discourse participants. Furthermore, they are characteristically unaffected by a variety of linguistic embedding environments, such as negation, conditionals, and questions. They are thus extremely suitable for investigating the interplay of linguistic and domain-general processes in language comprehension.

The following discussion is structured as follows. This section briefly reviews the basic theoretical background (for a detailed recent review, see Beaver & Geurts 2012). Section 2 surveys methodological approaches, from basic response measures to more fine-grained online processing measures, and their application to the experimental study of presuppositions. Section 3 turns to theoretical issues concerning presupposition projection and discusses experimental investigations of cases in which presupposed content does not project, of the nature of the projected content, and of the cognitive processes involved in resolving presuppositions in context.

1.1. The Status of Presuppositions

The notion of presupposition first arose in connection with definite descriptions. Frege (1892) argued that the existence of an entity satisfying the descriptive content is a *Voraussetzung* (i.e., a precondition or presupposition) for the containing sentence to have any meaning. In a similar vein, Strawson (1950), arguing against Russell (1905), claimed that definite descriptions that failed to refer led to sentences that are neither true nor false (rather than plain false, as Russell would have it). Definites have continued to receive ample attention (see, e.g., Reimer & Bezuidenhout 2004), but a key insight of early research on presupposition (Karttunen 1973, 1974; Stalnaker 1943, 1974) was that the key properties of definites are shared by a fairly wide variety of linguistic expressions, including factive verbs (e.g., *know*), aspectual verbs (e.g., *stop* and *continue*), iteratives (e.g., *again* and *too*), and clefts. Subsequent decades saw a wide variety of work trying to account for so-called presupposition triggers and their properties in unified theoretical frameworks. More recently, a need for differentiating different classes of triggers has been recognized.

A central feature of presuppositions is that their status contrasts with that of the truth-conditional at-issue content (what Roberts 1996 referred to as "proffered" content). Presuppositions are backgrounded (not at-issue) and (typically) taken for granted, as illustrated below. A false presupposition commonly yields a sentence that is neither true nor false.

(1a) John climbed Mt. Everest again this year.
(1b) Professor Jones stopped failing all of his students.
(1c) It was Sue who broke the window.

Intuitively speaking, example 1*a* asserts this year's climbing achievement, but presupposes a previous one. Example 1*b* asserts that from the relevant point on forward, Professor Jones has not been

failing his students, but presupposes that he did so previously. Finally, example 1*c* asserts that Sue is the culprit, but takes for granted that someone broke the window. Another indication that the relevant content is not at-issue is that denying these sentences generally does not involve denying the presupposed content; furthermore, even "no" answers to their yes/no-question counterparts involve a commitment to the presupposition (barring further elaborations).

1.2. Presupposition Theory: Semantics Versus Pragmatics

One way of capturing the fact that sentences with unmet presuppositions are neither clearly true nor false is to abandon the bivalent nature of classical logic and to assume a third truth value, commonly represented by a number sign (#). When a presupposition is false, an atomic sentence containing its trigger will have just that truth value. Trivalent logics based on Kleene (1952) were used early on to capture the nature of truth-value judgments for presuppositional sentences, and recent years have seen a revival of trivalent semantic theories (Beaver & Krahmer 2001, Fox 2008, George 2008), as well as of supervaluationist versions thereof (van Fraasen 1968).

Another family of approaches, following Stalnaker (1973, 1974), advances a pragmatic approach to presuppositions. In the broadest sense, this view sees the term "presupposition" as encompassing everything mutually taken for granted in a given discourse. This is Stalnaker's Common Ground, represented by a set of possible worlds consistent with what is mutually assumed. Generally speaking, the assertion of a sentence updates the Common Ground, but if this is associated with a presupposition, it can happen only if the Common Ground entails what is presupposed. Thus, what is regarded as lack of a truth value on trivalent approaches is now regarded as an inability to update a Common Ground. On a purely pragmatic approach, there is a question of how a given utterance of a sentence becomes associated with a presupposition, if presuppositions are not encoded in the semantics of any lexical entries. Stalnaker remains somewhat noncommittal in this regard. However, as he points out, it is perfectly compatible to assume that (at least some) pragmatic presuppositions are due to semantically encoded presuppositions [cf. the notion of "Stalnaker's bridge," introduced by von Fintel (2004)]. For present purposes, we maintain the common assumption that specific expressions are standardly associated with presuppositions, without prejudging just how this association is brought about.

Within linguistics, dynamic theories (starting with Kamp 1981, Heim 1983) adopt Stalnaker's perspective of presuppositions as constraints on context updates, but incorporate it directly into a revised semantic framework. Heim's File Change semantics proposes to see sentence meanings themselves in terms of their context change potential. The resulting system combines aspects of trivalent and pragmatic approaches by providing a partial semantics where failure of context update plays the role of the third truth value. Discourse Representation Theory (DRT; van der Sandt 1992, Geurts 1999) also formally encodes contexts as part of the semantics. It provides a representational framework where contexts are characterized in terms of Discourse Representation Structures (DRSs), and adding sentences to a discourse amounts to adding their own DRSs to the overall representation of the discourse. Presuppositions are considered a type of anaphora in this framework, meaning that their contributions to DRSs have to be linked to existing parts of the Discourse Representation.

1.3. Presuppositions Versus Other Aspects of Meaning

Recent research on presuppositions has reconsidered the boundaries between different aspects of meaning in various ways. For example, Tonhauser et al. (2013) compare a variety of expressions and constructions which project out of embedded environments, including various types of

presupposition triggers as well as conventional implicatures, and argue for a unified theory of their projection behavior.[1] In addition, various proposals for distinguishing types of presupposition triggers have been made, such as lexical versus resolution triggers (Zeevat 1992), soft versus hard triggers (Abusch 2002), strong versus weak triggers (Glanzberg 2005), and triggers that entail their presupposition versus ones that do not (Sudo 2012). Some of these have been the subject of initial experimental investigations, discussed below.

One approach that has been particularly important in experimental work analyzes certain types of presupposition triggers pragmatically, and assimilates the relevant inferences to those of implicatures (Simons 2001, Abusch 2010, Chemla 2009b, Romoli 2015). Given prior experimental work on implicatures (for a recent review, see Chemla & Singh 2014a,b), this approach lends itself to direct experimental comparisons, and some of the first results in this realm are discussed in Section 3.3.1. More generally, the overall project of classifying different aspects of meaning and their fine-grained properties constitutes an area where experiments can play a central role, by contributing systematic data on subtle aspects of interpretation.

2. METHODOLOGICAL APPROACHES AND FOUNDATIONAL ISSUES

I now turn to experimental approaches to presuppositions. These range from simple behavioral response measures to sophisticated investigations of the time course in online processing on the methodological side, and from foundational properties that are typically taken for granted in the literature to more complicated tests of subtle issues differentiating competing theoretical accounts. This section focuses on methodological approaches to detecting presuppositions and investigating their general properties.

2.1. Basic Response Measures

At the most basic level, the challenge of demonstrating experimentally that a presupposition normally assumed to be associated with a given expression is indeed present is largely parallel to the more general challenge of doing so for any aspect of linguistic meaning. Various standard tasks and response measures have been employed to this end.

2.1.1. Interpretation judgments. A general method for determining the presence of some specific aspect of meaning is to present a linguistic stimulus in form of a sentence and have subjects provide a judgment that directly reflects how they interpret it. Schwarz (2007) used a paraphrase selection task with ambiguous sentences to that effect. This study utilized syncretism for N(ominative) and A(ccusative) case marking in German, as in the following:

(2) Die Frau, die das Mädchen sah, hatte auch der Mann gesehen.
The $\text{woman}_{N/A}$ $\text{who}_{N/A}$ the $\text{girl}_{N/A}$ saw had also the man_{N} seen
'The woman that (saw the girl/ the girl saw) had also been seen by the man.'

Subjects had to select one among various paraphrases, which differed in whether the woman was said to have seen the girl or vice versa. Based on syntactic processing preferences, the former is independently preferred. However, the other interpretation ensures that the presupposition introduced by *also* (that someone else had seen the woman) is satisfied. The results indicate that

[1] Syrett et al. (2015) report a recent experimental comparison between these two aspects of meaning.

subjects indeed took this into consideration, as the paraphrase in line with the presupposition was chosen more frequently than in a presupposition-less control condition. Thus, even in abstract experimental settings with sentences out of context, interpretation choices seem to be affected by a desire for coherent interpretations, which may override independent processing factors biased in the opposite direction.

Abrusán & Szendrői (2013) employ a truth-value judgment task with sentences containing definites. Given the standard observation that nonreferring definites lead to a sense of "squeamishness" (Strawson 1950)—that is, reluctance to judge them to be either true or false—these authors provided a third option, labeled "can't say." Furthermore, they looked at a number of variations, based on notions such as topicality and verifiability, which have been argued to affect the strength and/or presence of squeamishness in the literature (Reinhart 1981, Lasersohn 1993, von Fintel 2004), as well as negated versions. Somewhat surprisingly, subjects quite consistently judged affirmative sentences as "false," with little use of the "can't say" option. However, the negated versions displayed significant variation in the distribution of judgments, which suggests that the existence condition of definite descriptions indeed has a status distinct from basic entailments, whose impact on judgments can furthermore be modulated by a variety of pragmatic effects. More recently, Zehr (2015) reported a similar study presenting sentences with the presupposition trigger *stop* paired with visual contexts. In this study, the third choice was introduced as "neither," which subjects choose approximately 50% of the time. This finding suggests that squeamishness can indeed be captured for affirmative sentences with this general method.

2.1.2. Acceptability ratings. Acceptability ratings of sentences offer a straightforward way of assessing the common assumption that presuppositions have to count as being taken for granted. However, it has been well known for a long time that this condition is not met in many felicitous uses. Such cases are commonly characterized as involving the repair mechanism of accommodation (see Lewis 1979 and Beaver & Zeevat 2007 for a recent survey), which essentially involves the hearers adjusting their assumptions about what the Common Ground is. One way of assessing the extent to which accommodation is available is to collect acceptability ratings in contexts that do not directly support the presupposition. These can be compared both to contexts that explicitly support the presupposition and to ones that are explicitly inconsistent with it.

Some early psycho-linguistic studies investigated related issues based on definite descriptions. For example, Carlson & Tanenhaus (1988) found that a sentence such as *The suitcases were heavy* is judged to make sense more frequently following the sentence *Bill hurried to catch his plane* than after the sentence *Bill hurried to unload his car*, presumably because the presence of suitcases is more salient in the former case.

In the more recent literature, Tiemann et al. (2011) presented a rather comprehensive set of studies involving acceptability measures. These authors investigated contexts with varying degrees of support for a variety of German presupposition triggers, including possessives, factives, iteratives, and aspectual verbs. For all these triggers, the use of presupposition triggers in contexts that do not explicitly support the presupposition was rated as less acceptable than both nonpresuppositional controls and variations with contexts that support the presupposition. At the same time, they were rated consistently as more acceptable than variants where the context is directly inconsistent with the presupposition (also see Schwarz & Tiemann 2012). This result suggests that while there is some cost associated with accommodation, the associated decrease in acceptability is only a moderate one.

Although Tiemann et al. (2011) found the same overall pattern for the various triggers in their study, the strength of the accommodation effect appears to be somewhat varied. This comes as no surprise, as it is commonly claimed that triggers differ substantially in their ease of

accommodation, although it is by no means clear how to account for this theoretically (Beaver & Zeevat 2007). Indeed, Kripke (2009) claimed that triggers such as *too* resist accommodation altogether. However, Tiemann et al.'s (2011) intermediate acceptability findings for *auch* 'too' (as well as for *wieder* 'again') indicate that accommodation is better than baseline controls with completely implausible adverbs or contexts that directly conflict with the presupposition. This finding is in line with observations by von Fintel (2008) and Chemla & Schlenker (2012) that accommodating *too* is possible when in line with plausibility in context. Singh et al. (2015) addressed this issue experimentally by using a stops-making-sense task, where subjects see a sentence unfold word by word as they press one button and are instructed to abort the trial with another button if it no longer makes sense to them. In this study, the authors compared the triggers *the* and *too* to presupposition-less controls in both plausible and implausible contexts, as in the following sentences:

(3) Context: Bill went to {a club / the circus} on Friday night.
Target: {A / the} bouncer argued with him there for a while.

(4) Context: John will go to {the pool / the mall} this morning.
Target: Peter will go swimming {tomorrow / too} after he gets back from school.

Rather strikingly, they found that in plausible contexts (. . . *a club* and . . . *the pool*, respectively) the presence of the presupposition trigger had no impact on the stops-making-sense task, and subjects overwhelmingly accepted the sentences for both triggers. In contrast, the presence of the trigger had a strong effect in implausible contexts, suggesting that accommodation is not viable. But in the plausible context, accommodation seemed to be just as readily available for *the* and *too*. Reading time effects suggest that it may nonetheless be slightly harder in the case of *too*, but it is clearly possible in plausible contexts.

In sum, acceptability rating tasks help shed light on the relation of presupposition triggers to context. The results to date support the traditional notion that presuppositions in general impose constraints on felicitous contexts of utterance, but they also suggest some need for distinctions between different types of triggers.

2.1.3. Assessing continuations. Another set of tasks that has proven useful in investigating presuppositions involves comparisons between different versions of continuations of a presuppositional sentence. Onea & Beaver (2011) and Destruel et al. (2015) used such tasks to investigate the exhaustive inference of focus and clefts (also see Velleman et al. 2011 for other triggers). Example 5, from Destruel et al. (2015), illustrates a forced-choice version of the task, where subjects had to indicate which of several continuations, including the ones below, best matched the context:

It was a necklace that Phillip bought his sister.
(5a) Yes, but Phillip also bought his sister a bracelet.
(5b) No, Phillip also bought his sister a bracelet.

For clefts, subjects frequently selected continuations such as the one in example 5*a*, in contrast to exclusive statements with *only*. The authors explained the difference between clefts and exclusives in terms of the status of the exhaustive inference, which is at-issue in the latter but not in the former, and thus is more or less likely to be targeted by *Yes* and *No*.

Other studies have used an acceptability rating version of this approach. Cummins et al. (2013) and Amaral & Cummins (2015) investigated various triggers in English and Spanish and tested the acceptability of *Yes*, *although* . . . and *No*, *because* . . . continuations:

(6) Q: Did Brian lose his wallet again?
A: Yes, although he never lost it before.
A′: No, because he never lost it before.

The triggers in their results seem to be grouped into two classes, which the authors related to the distinction between lexical and resolution triggers (Zeevat 1992). The latter are anaphoric and directly relate back to entities (or events) in the context, and include *again*, and *too*. The former involve cases where the presupposition is a requirement that comes with the asserted component of the trigger, as with *regret*, *stop*, *still*, and *continue*. For lexical triggers, the authors found systematically higher acceptability ratings for continuations parallel to example 6A′, whereas there was no difference in acceptability between the continuations for the resolution triggers. This observation is in line with Zeevat's distinction, as "the responses in condition [A] appear self-contradictory, if we assume that the presupposition is a logical prerequisite for the at-issue content of the trigger" (Amaral & Cummins 2015, p. 169).

2.1.4. Inference-based tasks. Another approach to testing for the presence of presuppositions in the interpretation of a sentence is to use tasks where the presence or absence of the potential presuppositional inference in question will be revealed indirectly through subjects' behavior. One such example can be found in the acquisition study by Dudley et al. (2015), who investigated the factive presupposition of attitude predicates such as *know*. A crucial question is to what extent children are sensitive to this aspect of meaning, specifically in contrast to nonfactive verbs such as *think*. Dudley et al. (2015) addressed this question through a guessing game, where an experimenter hid a toy in one of several boxes. Before the child guessed which box contained the toy, a puppet whispered in the experimenter's ear. The experimenter then relayed what the puppet said by saying *Lambchop* (*doesn't*) {*know/think*} *that it's in the red box*. If children pick up on the factivity of *know*, then their response behavior for the two verbs should differ. Dudley et al.'s (2015) results show that at least some of the three-year-olds in their study had an exquisite understanding of the factive component of *know*, including its presuppositional property of projection out of the scope of negation.

Another inference-based task is incorporated into the study of *again* by Tiemann (2014) (also see Tiemann et al. 2015), who presented sentences such as *Linda received a pink lamp again* in contexts where Linda either had or had not received a pink lamp previously. For one-third of the items, a comprehension question assessed the extent to which the subjects accommodated Linda receiving a pink lamp on a previous occasion when the immediate context did not support this assumption. In particular, the subjects had to answer whether Linda had received one or at least two pink lamps in total. Somewhat surprisingly, the presupposition of *again* hardly affected the subjects' answer choices in the nonsupporting context; that is, they overwhelmingly chose "one" as the answer. The authors interpreted this result as suggesting that accommodation is a last-resort mechanism that is to be avoided if at all possible. Alternatively, one might explain the subjects' behavior in terms of narrowly interpreting the question with regards to the immediate context, but even so, it is very interesting that the presupposition did not seem to counter such a restrictive interpretation at all.

Domaneschi et al. (2013) also used comprehension questions to assess the presence of presupposition-based inferences. They auditorily presented short stories that contained a variety of presupposition triggers. The key measure came from a true/false comprehension question, which related directly to the presuppositions, none of which was explicitly supported in the story. A variation in cognitive load, based on a simple visual memory task, added an additional perspective on the processing efforts involved. Domaneschi and colleagues were interested in potential

differences between triggers in their likelihood of accommodation (or at least processing of the presupposed content in the first place). Their theoretical approach followed that of Glanzberg (2005) in distinguishing strong and weak presupposition triggers, which differ in whether the presupposed information is obligatorily processed in nonsupporting contexts (as with strong triggers such as factive verbs) or not (as with weak triggers, such as iteratives like *again*). Their results suggest that these two types of triggers indeed differ in terms of how present they are when answering questions about the previously heard text, in that accuracy is overall much lower for weak triggers. The results for *again* in particular seem to accord with the finding from Tiemann's (2014) study, where its presupposition was essentially ignored when the relevant question was answered. In addition to the differences in accuracy, Domaneschi et al. (2013) found that change-of-state verbs and iteratives are particularly sensitive to the cognitive load manipulation; that is, the effect of cognitive load does not line up directly with the distinction between weak and strong triggers. Although these findings are in line with the distinction between strong and weak triggers, alternative explanations (for instance, in terms of the level of backgroundedness or immediate relevance for the current topic of discussion when the trigger is encountered) should also be explored.

2.2. Temporal Measures

Much can also be learned from closer investigations of the time course of presupposition interpretation and corresponding response behavior. I first discuss studies of response and reading times, and then describe more direct measures of online processing using eye tracking.[2]

2.2.1. Reading and response times. One use of response time measures in the study of presupposition is to help establish a systematic empirical basis for the distinction between presupposed and asserted content. As discussed in Section 2.1.1, truth-value judgment tasks do not always provide straightforward evidence for such a distinction, as speakers quite happily judge sentences that would standardly be assumed to involve presupposition failure as false, rather than infelicitous. Two studies have investigated the time course of truth-value judgments to assess whether false judgments based on false-asserted versus false-presupposed content might be differentiated in terms of their time course.

First, Kim (2008) investigated the presupposition of *only*. *Only the girls have books* commonly is taken to presuppose that the girls have books. Kim's experiments present such sentences in visual contexts that either did or did not conform to this presupposition (i.e., they showed the girls as having books or not). The truth of the asserted content (whether or not nongirls had books) was also varied across conditions. Subjects took longer to respond when their responses were based on an unmet presupposition than when they were based on false-asserted content. Kim interpreted this result as a reflex of the backgrounded nature of presuppositions, which affects the verification procedure employed in the task: Presuppositions are literally taken for granted and not initially verified, in contrast to asserted content, which leads to longer reaction times in falsifying them. Schwarz (2015a) took a similar approach to the study of the existence implication of definite descriptions, again by asking subjects to provide truth-value judgments on sentences relative to visual contexts that falsify either the asserted or the presupposed content. Indefinites served as a control, where essentially the same information was asserted in both conditions. The results yielded a significant interaction between the type of determiner and the contextual information

[2] Few neurolinguistic studies of presuppositions as a general phenomenon exist to date, but see van Berkum et al. (2003) and Burkhardt (2006) (and subsequent work by these authors) on definite descriptions.

affecting which part of the sentence is falsified. This finding suggests that the status of the existence implication is indeed distinct from that of the main asserted content, and thus supports presuppositional analyses of definites in the tradition of Frege (1892) and Strawson (1950), in contrast to accounts in the tradition of Russell (1905), which see it as a mere entailment.

Second, in a reading study, Clifton (2013) also looked at definite descriptions but focused on the effect of the uniqueness presupposition. A context sentence was used to establish whether there was one or multiple of the relevant items (e.g., *In the kitchen . . .* versus *In the appliance store . . .*), and the following target sentence contained either a definite or an indefinite description ({*The / A* } *stove*). Despite clear intuitions about the variation in the felicity of the materials, Clifton found no effect whatsoever in a simple self-paced reading study. However, a follow-up experiment with memory load in the form of a simple arithmetic task between reading the sentence and answering a comprehension question found a clear effect in the region following the definite, with longer reading times in the multiple-item condition. This finding highlights an important methodological aspect of studying presuppositions, namely that subjects may not fully engage in linguistic processing in an experimental setting when the task at hand does not require it.

Self-paced reading studies have also been used to study other triggers. In addition to the paraphrase selection task for ambiguous sentences containing *also* discussed above, Schwarz (2007) also reported self-paced reading results for both German and English on disambiguated versions of the sentences, where the presupposition was either met or not supported within the presented sentence. Reading times increased significantly on the region containing *also* in the latter case. Along the same lines, Tiemann et al. (2011) reported self-paced reading results for various triggers as well, with parallel slowdowns on either the region containing the trigger or the one following it (see Tiemann 2014 for additional results on *again*).

The lesson from these studies is twofold. On the one hand, presuppositions do not seem to receive much attention in initial phases of sentence verification, given the response-time delays for judgments based on false-presupposed information. On the other hand, the reading time studies suggest that presupposed information is rapidly integrated with the context in reading, as the slowdowns in reading times on trigger regions in nonsupporting contexts can occur only if the presupposed information is indeed accessed and related to the context. Though future research will need to investigate the tension between these findings further, it is likely that the nature of the task plays a crucial role.

2.2.2. Fine-grained measures of online processing. While the response time and self-paced reading studies discussed above help shed light on the time course of presupposition interpretation in online processing, they do so only at a fairly coarse-grained level. A more fine-grained temporal perspective not only improves our general understanding of the cognitive processes involved in interpreting presuppositions but also helps us assess theoretical comparisons between presuppositions and implicatures. Various authors (including Bott & Noveck 2004, Huang & Snedeker 2011) have argued that implicatures are delayed in online processing, and if certain presupposition triggers in fact are a type of implicature, we may expect similar effects here.[3]

In recent years, more fine-grained methods for investigating online processing have been used to study presupposition as well. First, some of the self-paced reading studies described above have been extended to eye tracking during reading. Most relevantly, Schwarz & Tiemann (2012) investigated German sentences with *again* in contexts that either are or are not consistent with its

[3]But note that there is an ongoing debate on whether implicatures are indeed delayed (Grodner et al. 2010, Breheny et al. 2013, Degen & Tanenhaus 2015).

presupposition. They found slowdowns in the earliest fixation measures, including first fixation duration, in reading times on the verb that immediately follows *again*. These effects provide temporally fine-grained evidence that presuppositions are integrated with the discourse context more or less immediately (at least in unembedded contexts; see Section 3.3.3 for embedded cases). Along the same lines, Clifton (2013) also reported parallel effects to the self-paced reading data above in first-pass time measures.

Second, several recent eye-tracking studies have used the visual world paradigm (Tanenhaus et al. 1995) to investigate presupposition processing. These studies involve visual stimuli with a number of alternative candidates for reference, paired with auditory linguistic stimuli. Participants' eye movements are monitored as the linguistic input unfolds, and the general design is set up so that looking preferences can be interpreted as indicating the availability of the interpretation of interest at a given point in time. Chambers & Juan (2005, 2008) investigated *another* and *return* with this method and found rapid shifts of fixations based on the respective presuppositions. More recently, Romoli et al. (2015) looked at English *also* in comparison with the asserted part of *only*. They found shifts in eye movements based on the presupposition of *also* as early as 400 ms after its onset, indicating that the presupposition is utilized in determining the referent before further disambiguating information is introduced.

Schwarz (2015b) contrasted the same two expressions and observed a shift in fixations as early as 200–300 ms after the onset of *also*, suggesting that the presupposition introduced by *also* is immediately available and utilized in identifying the referent. Another experiment looked at the interpretation of stressed *also*, which associates with the subject of the sentence, again in comparison to *only*. Whereas *also* again gave rise to an essentially immediate shift in fixations toward the target (starting 300 ms after the onset of *also*), the exclusive inference introduced by *only* did not give rise to a parallel shift until 700 ms after its onset. Extending this approach, Schwarz (2014) compared a hard trigger and a soft trigger, *again* and *stop*, to assess whether the potentially pragmatic nature of the latter might lead to differences in processing speed, given related findings for implicature (Huang & Snedeker 2011). However, both triggers very much paralleled the time course observed in the previously discussed studies on *also*, with immediate shifts in fixations based on the presupposed information.

Thus, the results from these studies, together with the reading results given above, do not support the notion that at least some presuppositions are pragmatically computed in a costly manner associated with processing delays. This finding may be most naturally compatible with accounts that assume all presupposed content to be encoded conventionally, but it is also possible that we are looking at rapid pragmatic effects, so the results per se do not settle the question about the source of presupposed content. Nonetheless, they provide the most direct and time-sensitive evidence yet that presupposed information is available and utilized as soon as the presupposition trigger is introduced.

3. PRESUPPOSITIONS IN EMBEDDED ENVIRONMENTS

3.1. The Phenomenon of Projection

Another hallmark property of presuppositions concerns the persistent presence of presupposition-based inferences arising from presupposed material introduced in embedded contexts [Karttunen 1974; also see Chierchia & McConnell-Ginet's (1990) "family-of-sentences" tests]. For example, negation, questions, and conditionals have the effect that the at-issue content of the clause they embed no longer is conveyed by the entire sentence. But presupposed content remains untouched, as shown by the following variations:

(7a) John didn't climb Mt. Everest again this year.
(7b) Has Professor Jones stopped failing all of his students?
(7c) If it was Sue who broke the window, she'll have to pay for it.

Yet another intricacy of projection phenomena is that they interact with the linguistic environment. Whereas example 8*a* displays standard projection and requires a context where a prior climbing is taken for granted, the variant in example 8*b* comes without any contextual constraints.

(8a) If John was in Nepal, then he climbed Mt. Everest again this year.
(8b) If John climbed Mt. Everest last year, then he climbed it again this year.

While it is intuitively clear that this difference in projection is due to the content of the antecedent, it is no small feat to capture the effect theoretically. Indeed, doing so has been a key challenge in the literature.

3.2. Theoretical Approaches to Projection

In Stalnaker's pragmatic approach, projection phenomena are interpreted as the result of how context updates proceed for complex sentences, as is most simply illustrated for conjunction:

(9) John climbed Mt. Everest last year and he climbed it again this year.

Stalnaker (1973, 1974) explains the lack of an overall presupposition here by arguing that the first conjunct is added to the context before the second conjunct is considered, thus guaranteeing that any initial context can be updated with the conjunction as a whole. Stalnaker proposes to extend this line of reasoning to other connectives as well.

In dynamic semantic approaches, capturing projection requires formulating the appropriate context change potentials for the relevant connectives. For example 9, this process entirely mirrors Stalnaker's approach. For conditionals, assuming the equivalent of a material implication analysis, the update procedure removes those worlds from the initial context where the antecedent is true and the consequent is false. More technically, the procedure for updating a context c with a conditional *If p, then q* is characterized as follows (Heim 1983):[4]

(10) $c + (\text{If } p, \text{ then } q) = c - ((c + p) - ((c + p) + q))$.

Crucially, interpreting the consequent q involves an update relative to only the original context as updated with the antecedent ($c + p$), and not the original context c alone. This accounts for the fact that example 8*b* imposes no constraints on c, as the fact that $c + p$ is a subset of p (and thus entails the presupposition of q, that John climbed Mt. Everest prior to this year) ensures that update with q cannot fail. DRT offers an alternative dynamic approach, in which projection is on par with anaphora resolution within discourse representations. Though the overall empirical predictions are similar, there are some key differences, some of which play a direct role in the experimental investigations discussed below.

[4]The plus sign represents the operation of context update, which in the simplest case amounts to a set-theoretic intersection of propositions construed as sets of possible worlds.

In order to capture projection in trivalent approaches, the relevant connectives are interpreted in terms of nonclassical truth tables. The Strong Kleene version of such a truth table (Kleene 1952) successfully captures projection phenomena by positing that complex sentences are assigned the value # just in case one of its atomic sentences has that value and the truth values of the other atomic statements do not suffice to determine the truth value of the entire sentence based on standard logic. For instance, example 8*b* always receives a classical truth value because if the antecedent is false the entire conditional will necessarily be true (again assuming a material implication analysis), regardless of whether the presupposition that John had climbed Mt. Everest before this year is true or not. And if the antecedent is true, then this presupposition is necessarily also true, and the truth of the conditional depends entirely on the truth of the nonpresuppositional part of the consequent.

3.3. Experimental Approaches to Projection

Given the central role of projection in theoretical research, much of the experimental work has been concerned with projection phenomena as well. A number of studies have investigated variation in projection, specifically with respect to the strength of the projection effect and the availability of nonprojecting (local) interpretations. Other studies have been concerned with the exact nature of the overall presupposition of sentences containing triggers in embedded positions. Yet another set of studies has investigated presupposition resolution in context, within both complex sentences and the larger discourse context.

3.3.1. Variation in projection. Much of the discussion in the literature concerned with identifying differences between (classes of) presupposition triggers is based on the observation that some triggers seem to project more persistently than others. Abusch (2002, 2010) considers examples such as the following:

I don't know if Paul participated in the race, . . .
(11a) but, if he won, he must be very proud.
(11b) ?? but, if Mary participated too, they probably had a drink together just after.

The presupposition of *win*, that Paul participated in the race, does not seem to be globally present, as it would be inconsistent with the context sentence. However, the global presupposition of *too*, that someone else (salient in the context) participated in the race, seems to give rise to a certain amount of oddness. Jayez et al. (2015) investigated this contrast experimentally by looking at presupposition triggers in the antecedent of conditionals. Looking at French *aussi* 'too', *regretter* 'regret', and clefts, these authors presented evidence that the distinction is not entirely robust and that it seems to interact with other contextual factors. They argued that their results are consistent with a three-way distinction between presupposition triggers, in line with Jayez (2015).

Smith & Hall (2011) investigated the projection strength of various presupposition triggers, as well as that of conventional implicatures, in a host of "family of sentences" environments (Chierchia & McConnell-Ginet 1990). They used a "surprisal" judgment, in which subjects have to assess how surprised they would be to learn that the presupposed proposition holds after hearing a sentence containing the trigger. Their findings are uniform for conventional implicatures and presuppositions (which they argued to speak in favor of a unified treatment of projection, as in Tonhauser et al. 2013) but also suggest that projected content has a somewhat weaker presence than nonprojected (i.e., asserted or unembedded presupposed) content. They also found some variation between triggers, though it does not line up neatly with theoretical differentiations proposed in the literature.

Just because a presupposition does not project does not mean that it disappears entirely. Indeed, many accounts assume that what happens in (at least some of) such cases is that the presupposition gets locally accommodated (as first proposed by Heim 1983). This assumption offers an explanation for the fact that sentences such as *The king of France is not bald—because there is no king of France!*, discussed by Russell (1905), are quite acceptable, despite the incompatibility that would be expected on the basis of a global existence presupposition of *the*. The consensus in the theoretical literature (beginning with Heim 1983) has been that local interpretations are dispreferred, though this idea is based only on individual intuitions. More recently, Chemla & Bott (2013) offered the first experimental evidence to support that assessment by using a truth-value judgment task with sentences such as example 12 and looking at reaction time measures.

(12) Zoologists don't realize that elephants are reptiles.

The factive verb *realize* presupposes the truth of its complement clause, and on its global interpretation, this presupposition prevails even in the context of negation. However, a local interpretation would have that inference negated. In the latter case, the sentence should be judged true, whereas in the former, it should be judged false. Both types of responses were given by subjects throughout the experiment, but the "true" responses took significantly longer than the "false" responses. Chemla and Bott interpreted this finding as evidence for traditional, semantic accounts that take local accommodation to be a last-resort repair strategy. In contrast, they argued the results to be incompatible with pragmatic accounts à la Schlenker (2008a), which assume that the local reading corresponds to a literal semantic reading, whereas the global reading requires additional pragmatic inferencing.

Romoli & Schwarz (2015) utilized a different task to investigate the speed of local interpretations of the presupposition introduced by *stop* under negation, namely a "covered box" version of a picture selection task (Huang et al. 2013). In this experiment, the subjects had to select a match for a given sentence amongst various pictures, one of which was "hidden." The basic idea is that if the presuppositional inference of interest plays a role in subjects' interpretation, then they should choose the covered box when no overtly shown image is compatible with the inference. This experiment compared cases where the overt picture supported the presupposition with ones where it did not. The acceptance rates were much lower for target pictures corresponding to the local interpretation. Furthermore, the response times for target choices were slower for local target acceptances than for global ones, in line with the results from Chemla & Bott (2013).

Extending this approach to other populations, Bill et al. (2014) and Kennedy et al. (2015) used the same task, though without measuring response times, to test the interpretation of presuppositions under negation in children and subjects with Broca's aphasia, respectively. Both groups were much more likely than healthy adults to adopt a global presupposition interpretation. Furthermore, these two studies compared presuppositions with implicatures of strong scalar items (*not all*); here, the subjects with Broca's aphasia patterned with healthy adults and were more likely than children to base their response on the implicature. This double dissociation provides a strong argument against an entirely uniform treatment of (certain) presupposition triggers and implicatures, as proposed, for example, by Romoli (2015).

3.3.2. What exactly projects?. The exact nature of the content projecting from various embedding environments has been controversial in the theoretical literature. Thus, experimental methods have been used to clarify the empirical picture, with a focus on embedding under quantifiers and sentential connectives.

3.3.2.1. *Presuppositions of quantified sentences.* Chemla (2009a) investigated the presuppositions of quantificational sentences, such as *No student knows he's lucky*. The theoretical literature contains opposing views as to whether these introduce universal or existential presuppositions, that is, whether such a sentence requires a context where all students are in fact lucky or whether it suffices for some of them to be (Heim 1983, Beaver 2001). Chemla (2009a) presented sentences such as the one above, as well as sentences with a range of other quantifiers, to subjects and asked them to judge whether (or, in a second experiment, how strongly) the sentence suggests that all of the students are lucky. Judgments for the quantifier *no* patterned with those for *every* and indicated a universal presupposition, whereas universal inferences for numerical quantifiers (e.g., *more/less than 3*) were less strongly supported. This finding of variation in the projected presupposition is theoretically important, as traditional theories predict uniform projection one way or another. Chemla proposed to capture the results in terms of Similarity Theory (Chemla 2009b).

More recently, Tiemann (2014) reported a German study using eye tracking during reading, which manipulated context sentences for quantificational target sentences with respect to whether the relevant presupposition is met universally or not. She found slowdowns in reading time for *jede* 'every' in nonuniversal contexts, but not for *ein* 'one.' Parallel to Chemla's findings, this result suggests that the nature of the projected presupposition depends on the quantifier. Together, these results call for further in-depth exploration, both theoretical and experimental.

Another recent study, by Geurts & van Tiel (2015), investigated the effects of presuppositions on domain restriction. Pairing simple geometrical figures with sentences in a truth value judgment task, these authors looked at quantified sentences such as *Each of these 7 circles has the same color as the square that it is connected to*. Rather strikingly, they found that even a picture in which only 2 out of the 7 circles presented are connected to the square next to them and have the same color yielded a substantial amount of "true" judgments—up to 68% of the time, on the basis of the visual display. The authors analyzed this finding within the framework of DRT and proposed that such judgments are based on intermediate accommodation. Another finding, which seems to directly contradict that of Chemla (2009a), is that acceptance of sentences with *none* are at ceiling level throughout, suggesting an existential rather than universal presupposition. Even though the tasks are quite different in the two studies, the results constitute a puzzle that needs to be further investigated.

3.3.2.2. *Sentential connectives.* I now turn to embedding under sentential connectives. Here there is substantial disagreement in the theoretical literature regarding whether a presupposition trigger in the consequent of a conditional (such as the possessive definite in example 13) gives rise to a conditional presupposition (example 13*a*, for instance, on dynamic semantic accounts) or a nonconditional one (example 13*b*, for instance, on DRT accounts):

(13) If Al goes surfing, he'll wear his wet-suit.
a. If he goes surfing, he has a wet-suit. b. He has a wet-suit.

Both interpretations seem to be attested, but theories differ in terms of which one is regarded as basic. Romoli et al. (2011) provided the first experimental exploration of this topic, using the covered box picture-matching task discussed above, and argued that their results favor accounts that predict a conditional presupposition as the basic one. Their results also support the notion that whether or not the presupposition intuitively can be regarded as dependent on the content of the antecedent affects judgments.

Another set of experiments on projection has investigated the role of incrementality. Standard dynamic accounts assume that presuppositions have to be supported in their context by material

that precedes the trigger. A central idea emerging from Philippe Schlenker's work (Schlenker 2008a,b; 2009) is that presupposition projection can be broken down into two components. On the one hand, there is a (trivalent or supervaluationist) semantic component, which crucially is symmetric—that is, insensitive to effects based on linear order. On the other hand, order-based incremental effects (as in example 9) are attributed to left-to-right processing but are in principle violable. This analysis opens up interesting questions about presupposition processing.[5] Chemla & Schlenker (2012) studied this issue more closely and tested presupposition triggers in conditionals, disjunctions, and *unless*-sentences in configurations where the presupposition trigger appears either in the linearly first or second clause. In an inference judgment task, they found that subjects endorse conditional inferences more strongly than nonconditional ones, regardless of where the presupposition trigger is introduced. They interpreted this finding as support for a symmetric theory of presupposition satisfaction, where material introduced later on in the sentence can, in principle, provide support for an earlier presupposition. Schwarz (2015c) varied this paradigm by looking at conditionals in a covered box picture-selection task and varying the position of the *if*-clause. The results of this study were more mixed, in that the *if*-clause initial conditions suggest a fairly strong role of incrementality, whereas the *if*-clause final conditions are more in line with symmetric predictions.

Hirsch & Hackl (2014) investigated the effects of incrementality in disjunctions. These pose a potential challenge to a general processing-based effect of linear order, as they seem entirely symmetric, as in the following example (attributed to Barbara Partee by Roberts 1989):

(14) Either the bathroom is in a funny place, or there is no bathroom.

In contrast to conjunctions, a trigger in the first disjunct does not generally project globally; in other words, example 14 appears to be equivalent to a variant with the disjuncts reversed. However, Hirsch & Hackl (2014) argued that there is an additional confound, as a global presupposition interpretation would be inconsistent with the nonpresuppositional disjunct, and that each disjunct is independently required to be a live possibility in the global context. Rather than predicting an overall asymmetry in projection parallel to conjunction, an incremental account of projection then merely predicts a processing effect due to a garden path effect. The authors assessed this prediction by having subjects select the more natural of two sentences, one parallel to example 14 and the other with an additional presupposition trigger that is consistent with a global interpretation of the other trigger. The results were in line with the authors' predictions in that a stronger preference emerges for the version consistent with a global presupposition when the trigger appears in the first conjunct. In contrast, control sentences that at no point suggest a global presupposition interpretation display no effect of order.

3.3.3. Presupposition projection and resolution in context. A final set of studies relating to projection has been concerned with the resolution of presuppositions in context, either intrasententially or in the discourse context, and its time course in processing. First, in two reading time studies using eye tracking, Schwarz & Tiemann (forthcoming) found that embedding of presupposition triggers modulated processing effects. In the first study (mentioned in Section 2.2.2, above) immediate eye movement effects on the critical word were found when the context was inconsistent with the presupposition, but only when the trigger (German *wieder* 'again') was outside of the

[5] Schlenker also argues his account to be more satisfactory than dynamic semantics in terms of explanatory adequacy, as it does not stipulate the projection properties of specific connectives.

scope of negation. No effects of context emerged when the trigger was embedded under negation, and follow-up studies suggest that this is not due to a general availability of local interpretations. In the second study, presuppositional support for *wieder* in the consequent of conditionals was introduced in varying locations, namely in the antecedent or in a context sentence. Schwarz & Tiemann (forthcoming) interpreted the results from this study as suggesting that the hierarchical distance in terms of the projection search path assumed by DRT directly affects reading times on the critical region. Such an effect is less straightforward to derive on nonrepresentational accounts (such as dynamic semantics).

Kim (2015), using the visual world paradigm, took a different angle and investigated the effects of discourse structure on the selection of an antecedent for *also*. She did so by presenting multisentence discourses, which provide various possible antecedents for *also* in the final target sentence. In two initial comprehension studies, Kim asked subjects to choose one of several descriptions of what the sentence with *also* conveyed, which reflects how they resolve its presupposition in the discourse. While there was a general preference for linearly local antecedents in the comprehension studies (where *also* was understood relative to the immediately preceding sentence), a structurally (but not linearly) local interpretation also became available when the discourse structure was manipulated. In a visual world eye tracking experiment, Kim also found a preference for structurally local interpretations. The eye movement results for the condition that involves a structurally local antecedent furthermore add to the evidence from the two studies described above, showing that the presupposition of *also* is available immediately in online processing.

4. CONCLUSION

While the experimental study of presuppositions is still at an early stage, substantial progress has been made, both in methodological developments and toward settling controversial issues. With these tools at hand, ever more intricate issues can now be empirically investigated in a systematic way, and the future is likely to bring a closer overall integration of theoretical and experimental research. Beyond informing the specific realm of presupposition theory, results from such work will also bear directly on larger architectural issues concerning the relation between language-specific and domain-general processes in language comprehension.

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