Processing temporal presuppositions: an event-related potential study

Processing Temporal Presuppositions: an ERP study*

Short title: Temporal presuppositions

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Abstract

The ability to efficiently process presuppositions, which contain information that the speaker believes to be in the background to the conversation, is essential for effective communication. To get a deeper understanding of the nature and the time-course of temporal presupposition processing, we examined event-related potential (ERPs) evoked by the word *again* in two types of sentence contexts. The word *again* was presented in contexts that supported a presupposition (e.g., *Jake had tipped a maid at the hotel once before. Today he tipped a maid at the hotel* ***again****...*) or violated it (e.g., *Jake had never tipped a maid at the hotel before. Today he tipped a maid at the hotel* ***again****...*). The presupposition violation was associated with increased amplitudes of the P3b/P600 but not the N400 component. We argue for the centrality of the P3b/P600 component for presupposition processing. These findings demonstrate rapid integration of lexical presuppositions with contextual knowledge.

Keywords: temporal presupposition, ERPs, P3b/ P600, N400, presupposition violation

1. Introduction

Natural language is highly adaptive: the very same message can be used to convey many distinct meanings depending on the communicative context. This *context-sensitivity* is one of the defining characteristics of language. One important way in which communicative contexts differ is with respect to what information is already shared among the participants in a conversation. Consider the use of the definite determiner *the* in sentence (1).

(1) *Mary saw the tiger.*

Which tiger Mary saw is highly context-dependent. For example, if we are at a zoo, then this sentence will likely convey that Mary saw the tiger at the zoo. In contrast, if a tiger is on the loose in town, then the sentence will likely convey that Mary saw that tiger. Critically, however, the determiner *the* in (1) carries the *presupposition* that there exists a unique tiger in the context. If there is more than one salient tiger in the context, or no tigers at all, then the sentence cannot be felicitously used, and its presupposition will have been *violated*. More generally, presuppositions impose requirements on the conversational context. If a sentence carries a presupposition, then it will only be felicitous if the context satisfies that presupposition (Caffi, 2006; Heim, 1983; 1992; Kamp, 2008; Katz, 1973; Simons, 2006; Van Der Sandt, 1992).

Presuppositions are "triggered" by a distinct class of words, referred to as *presupposition triggers*. In English, the words *the*, *stop*, and *again*, among others, act as presupposition triggers. These words signal the presence of shared background knowledge. For example, in (2), the trigger word *stop* asserts that the action of smoking was terminated at a certain time point and presupposes that the action has taken place

before that point.

(2) *John stopped smoking last year.*

In (3), the sentence asserts that the action of tipping occurred at certain time point, and the word *again* presupposes that this action was also performed on a previous occasion.

(3) *Jake tipped a maid at the hotel again*.

As seen from the examples above, trigger words differ in the type of shared information that they signal to be present in the background of a conversation. Depending on the nature of shared background information, several types of presuppositions have been previously examined, including the temporal presupposition triggered by the word *again* (Tiemann, Kirsten, Beck, Hertrich, & Rolke, 2015), the uniqueness presupposition triggered by the definite determiner *the* (Singh, Fedorenko, Mahowald, & Gibson, in press), change of state presupposition triggered by verbs *stop*, *continue*, *start* (Romoli & Schwartz, 2015), factive presupposition triggered by verbs *realize*, *discover*, *know* (Jayez, Mongelli, Reboul, & van der Henst, 2015), and additive presupposition triggered by particles *too* and *also* (Kim, 2015; Romoli, Khan, Sudo, & Snedeker, 2015).

Although theoretical discussions of presuppositions have gone on for decades, it is only recently that language researchers have begun to investigate the on-line processing of presuppositions (e.g., Chemla & Bott, 2013; Schwarz, 2007; 2015; Singh et al., in press; Tiemann et al., 2015). For example, some self-paced reading studies showed that presuppositions are available rapidly to the comprehenders (Tiemann et al., 2011, 2015; Schwarz, 2007). Tiemann and colleagues (2011) reported a delay in the reading of presupposition trigger words compared to non-presupposition controls. Further, presupposition triggers were processed much faster in supportive than in neutral or

unsupportive contexts (Tiemann et al., 2011, 2015). These results suggest that presupposition processing starts as soon as presupposition triggers are encountered.

Participants' behavior on sentences containing presupposition triggers has also been examined using eye-tracking (Chambers & Juan, 2008; Kim, 2015; Romoli & Schwarz, 2015; Schwarz, 2015). In these studies, participants were presented with an array of images that corresponded to alternative referents – the so-called *visual world paradigm* (Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995) – and the correct referent had to be identified based on the presence of a presupposition in an accompanying spoken utterance. The main finding of this research echoes the self-paced reading results: the processing of presuppositions started as soon as participants encountered presupposition triggers (and as early as 400 – 600 ms post presupposition trigger onset).

The most temporally sensitive findings on presupposition processing have been obtained using electroencephalography (EEG) or magnetoencephalography (MEG). In a few published EEG/MEG studies (Hertrich et al., 2015; Kirsten et al., 2014), researchers reported that presupposition processing began prior to and extended beyond the temporal window identified in eye-tracking studies. For example, Kirsten et al. (2014) had participants read 2-sentence passages, in which a presupposition trigger either conflicted with a preceding context (4.a) or not (4.b): [1]

(4.a) *Tina was in the zoo and saw some polar bears. She observed that the polar bear was aggressive.*

(4.b) *Tina was in the zoo and saw a polar bear. She observed that the polar bear was aggressive.*

The analysis of event-related potentials (ERPs) showed modulations in the neural activity evoked by presupposition triggers in infelicitous (4.a) vs. felicitous (4.b) sentences over two periods: the 350 – 450 ms (the N400 ERP component) and 500 – 700 ms (the P600 ERP component) time-windows. The N400 component, believed to be related to the ease of lexical access and/or integration of word meanings into the preceding context (Kutas, Urbach, & DeLong, 2005; Kutas & Hillyard, 1980; Kutas & Federmeier, 2011), was interpreted by the authors as emerging in (4.a) due to the mismatch between the context (in which there were multiple polar bears) and the semantics of *the* (which presupposes a unique polar bear). The P600, which has been previously linked to syntactic integration difficulty (Hagoort, Brown, & Groothusen, 1993; Osterhout & Holcomb, 1992), discourse reanalysis (Kolk & Chwilla, 2007; Kuperberg, 2007), and error correction processes within a noisy comprehension system (Fedorenko, Stearns, Bergen, Eddy, & Gibson, submitted; Gibson, Bergen, & Piantadosi, 2013), was construed by the authors as reflecting top-down reanalysis processes and attempts to incorporate the violated presupposition of (4.a) into a mental model of the discourse.

Hertrich et al. (2015) examined spectrotemporal characteristics of the MEG signal time-locked to the onset of presupposition triggers and found a suppression of spectral power within the alpha band (from 6 to 16 Hz) for infelicitous (4.a) vs. felicitous (4.b) sentences across two time-windows: 0 – 500 ms and 2000 ms – 2500 ms. The reduction of alpha activity is generally associated with increased mental load and cognitive effort (Bastiaansen & Hagoort, 2006; Klimesch, 1996; Shahin, Picton, & Miller, 2009). Although the timing of presupposition processing did not closely mirror the timing

reported by Kirsten et al. (2014), the authors provided a similar explanation of the biphasic pattern that they observed. In particular, the initial suppression of alpha power (0 – 500 ms) was taken to reflect violations of lexical expectancy, and the later one (2000 – 2500 ms) was linked with attempts to reinterpret presupposition triggers within the given context.

In the present study, we extend the existing work on the time-course of presupposition processing in several ways. First, this is the first study to examine ERP responses evoked by presupposition triggers in languages other than German (i.e., English). Examining ERP patterns evoked by presupposition triggers across multiple languages would shed some light on the issue of universality/language-specificity of the mechanisms of presupposition processing.

Second, we are the first to examine the ERP responses evoked during processing of temporal presuppositions, a type of presupposition triggered by the adverb *again*. The ERP/MEG studies of presupposition processing discussed above (Hertrich et al., 2015; Kirsten et al., 2014) examined the definite determiner (the uniqueness presupposition). Investigating ERPs evoked by other types of presupposition triggers (including the temporal presupposition trigger *again* examined here) is of theoretical importance as it will further inform the debate about the homogeneity / heterogeneity of presupposition triggers and the mechanisms used to process them.

Some researchers have argued or assumed that different types of presupposition triggers are processed by the same cognitive mechanisms and behave similarly in complex sentences (Heim, 1983; Van Der Sandt, 1992). Others, however, have suggested that presupposition is a heterogeneous phenomenon, with different triggers varying in

strength (Karttunen, 1971,1973). Extensive evidence for the latter view has since been provided (Abusch, 2005, 2009; Jayez et al., 2015; Romoli, 2015). The apparent heterogeneity of presupposition stresses the importance of probing a wide range of presupposition triggers in order to form generalizations about the mechanisms of presupposition processing (Chemla & Bott, 2013; Schwarz, 2015).

Presupposition triggers vary along another dimension: whether they entail their presuppositions. It has previously been argued that certain presupposition triggers, such as *stop*, both presuppose and entail their presuppositional content. If this is true, then this has the potential to confound experimental tests of presupposition violation. Under such an account, when participants encounter a presupposition violation, they would also be encountering an entailment violation. Any signal from the experiment could therefore be measuring either the violated presupposition or the violated entailment, making it difficult to isolate the processes underlying presupposition processing.

Sudo (2012) argues for heterogeneity among presupposition triggers, providing evidence that certain triggers, such as gendered reflexives, do not entail their presuppositions. For the current study, the relevant question is whether the trigger *again* entails its presupposition. Though a detailed investigation of this question is beyond the scope of this work, there have been previous suggestions that *again* may pattern with these non-entailing triggers (see Schwarz, 2014). Assuming that *again* is a non-entailing trigger, the present study would disentangle the effects of presupposition violations from entailment violations.

Following previous research, we here compare presupposition processing contexts in which presupposition triggers are not supported (5.a) vs. contexts in which they are

supported (5.b):

(5.a) *Jake had never tipped a maid at the hotel before. Today he tipped a maid at the hotel **again**, although the hotel paid its maids good wages.*

(5.b) *Jake had tipped a maid at the hotel once before. Today he tipped a maid at the hotel **again**, although the hotel paid its maids good wages.*

In (5.b), the control condition, the sentence stating that a person performed an action again follows a statement that the person has performed this action before, so the context supports the presupposition. In contrast, in the critical condition (5.a), the second sentence (containing *again*) follows a statement that the protagonist has never performed the relevant action before, leading to a conflict between the required presupposition and the stated information. Based on prior ERP studies of presupposition, we expect the processing of the presupposition trigger in an unsupportive context to lead to the modulation of the N400 and/or the P600 ERP components.

2. Methods

2.1. Participants

Thirty native English speakers (10 males; age 18-40 years) from the MIT Brain and Cognitive Sciences subject pool participated for payment. Informed consent was obtained in accordance with the MIT Committee on the Use of Humans as Experimental Subjects. Six subjects were excluded due to an excessive number of artifacts in the EEG signal (more that 25% of trials were excluded), leaving 24 participants for the final analysis.

2.2. Materials

160 experimental items were constructed with four conditions each: the control condition (6.a), the critical presupposition violation condition (6.b), the semantic violation condition (6.c), and the syntactic violation condition (6.d).

(6.a) Control: *Jake had tipped a maid at the hotel once before. Today he tipped a maid at the hotel* ***again****, although the hotel paid its maids good wages.*

(6.b) Presupposition violation: *Jake had never tipped a maid at the hotel before. Today he tipped a maid at the hotel* ***again****, although the hotel paid its maids good wages.*

(6.c) Semantic violation: *Jake had tipped a maid at the hotel once before. Today he tipped a* ***horse*** *at the hotel again, although the hotel paid its maids good wages.*

(6.d) Syntactic violation: *Jake had tipped a maid at the hotel once before. Today he tipped a* ***maids*** *at the hotel again, although the hotel paid its maids good wages.*

In the control and presupposition violation conditions, (6.a,b), the presupposition trigger *again* was the target word used in the analysis of presupposition processing. In the control, semantic violation, and syntactic violation conditions, (6.a,c,d), the direct object of the verb in the second sentence (*maid*/*horse*/*maids* above) was the target word. The semantic violation target words were created by taking the target words from the control condition and re-ordering them so that they did not fit with the context of the sentence (e.g., the word *horse* in (6.c) was the object acted upon in the control condition of another item). The syntactic violation target words were altered from the control condition to not agree with the determiner in number.

Semantic and syntactic violation conditions were included for two reasons. First, these types of linguistic manipulations have a long history in the ERP research, and there is general consensus about the types of ERP patterns that they elicit (Kutas &

Federmeier, 2011; Kutas & Hillyard, 1980; Osterhout & Holcomb, 1992, 1993). Detecting the expected ERP patterns for these conditions would therefore give us confidence in interpreting the results from the critical (presupposition violation) condition. Second, by including diverse linguistic violations, the likelihood that participants would expect a particular type of violation was diminished, thus potentially boosting the magnitude of the effect for each of the examined types of violations (Hahne & Friederici, 1999).

The 640 trials were distributed across four presentation lists following a Latin Square design (for the full list of stimuli see Appendix), so that each list contained only one version of an item (and 40 trials per condition). In addition, 30 filler trials were included in each list. Filler sentences (for an example, see (7)) mimicked the structure of the experimental items, but stated that an action was performed for the first time:

(7) *Percy had never received a present from his friends before. Today he received a present from his friends for the first time, although it wasn't his birthday.*

Thus, each participant saw 190 total trials.

To ensure that participants read the sentences for meaning, yes/no comprehension questions appeared after a quarter of the trials, constrained such that there were no more than three consecutive trials with a question. The correct answer was "yes" half of the time. Each list was pseudo-randomly divided into ten sets of trials, in order to give participants breaks as needed. Each set of trials contained four trials of each experimental condition, four or five questions, and three fillers. The order of trials was randomized separately for each participant.

2.3. Procedure

Participants were tested individually in a sound-attenuated and electrically-shielded booth where stimuli were presented on a computer monitor. Stimuli appeared in the center of the screen in white on a black background, time locked to the vertical refresh rate of the monitor (75 Hz). Each trial began with a pre-trial fixation (1000 ms), followed by 500 ms of a blank screen. The first sentence in each trial was displayed all at once (for 3,000 ms + 500 ms ISI). The second sentence in each trial was displayed word-by-word. For every trial, the critical words (*again* and *maid/horse/maids* in (6) above) were displayed for 450 ms, whereas all other words were displayed for 350 ms per word. Each word was followed by a 100 ms ISI, with an additional 400 ms after the last word of the sentence. Comprehension questions were displayed all at once (for 3,500 ms + 100 ISI) in aqua on a black background, and participants responded "yes" or "no" by pressing buttons on a gamepad. At the beginning of the experiment, participants were shown a small set of 4 practice items to familiarize them with the procedure. The experiment took approximately 1 hour.

2.4. EEG recording

EEG was recorded from 32 scalp sites (10-20 system positioning), a vertical eye channel for detecting blinks, a horizontal eye channel to monitor for saccades, and two additional electrodes affixed the mastoid bone. EEG was acquired with the Active Two Biosemi system using active Ag-AgCl electrodes mounted on an elastic cap (Electro-Cap Inc.). All channels were referenced offline to an average of the mastoids. The EEG was recorded at 512 Hz sampling rate and filtered offline (bandpass 0.1-40 Hz). Trials with blinks, eye movements, muscle artifact, and skin potentials were rejected prior to averaging and analysis.

2.5. Analysis

Twelve representative electrode sites from frontal, central, parietal, and occipital regions were included in the data analysis (F3, Fz, F4, C3, Cz, C4, P3, Pz, P4, O1, Oz, O2). ERP signals were time-locked to the onset of the target word and averaged across trials from 200 ms prior to the onset of this stimulus until 800 ms after onset. The time window from -200 ms to word onset was used as the pre-stimulus baseline.

3. Results

Participants were accurate in answering the comprehension questions (M = .88, SE = .01), which suggests that they were engaged in the task.

3.1. Semantic and Syntactic Processing

In the analysis of semantic violations, the mean amplitudes of ERPs evoked by target words in the control (8.a) and semantic-violation (8.b) conditions (repeated here from (6.a,c) above) were entered as the dependent variable in the repeated measures ANOVA:

(8.a) *Today he tipped a **maid** at the hotel again…*

(8.b) *Today he tipped a **horse** at the hotel again…*

In the analysis of syntactic violations, the mean amplitudes of ERPs evoked by words target words in the control (9.a) and syntactic-violation (9.b) conditions (repeated here from (6.a,d) above) were entered as the dependent variable in the repeated measures ANOVA:

(9.a) *Today he tipped a **maid** at the hotel again...*

(9.b) *Today he tipped a **maids** at the hotel again…*

The independent factors in both analyses were Violation (Absent vs. Present), Electrode Region (Anterior vs. Central vs. Posterior vs. Occipital), and Lateralization (Left vs. Midline vs. Right). All repeated measures for the within factors used the Greenhouse - Geisser correction. Figure 1 shows the waveforms evoked in response to semantically expected versus unexpected target words. Figure 2 shows the waveforms evoked in response to syntactically correct versus incorrect target words. Based on the visual examination of the evoked brainwaves and of the modulation of the mean global field power (MGFP) of the ERP amplitudes, a negative-going component was identified in the 300-450 ms time-window (the N400), and a positive-going component in the 450-750 ms time-window (the P600).

Processing costs for words that violate semantic expectations were identified in the N400 and the P600 time-windows. In the N400 time-window, a significant two-way Violation by Electrode Region interaction was observed: F (2, 38) = 12.35, $p < .001$, $\eta_p^2 = .35$. In particular, the difference in the magnitude of the N400 effect for semantically expected vs. unexpected words was present over the parietal (M (Violation) = -1.61, SD = 0.46 vs. M (No Violation) = -0.25, SD = 0.40) and occipital areas of the scalp (M (Violation) = -1.14, SD = 0.45 vs. M (No Violation) = 0.33, SD = 0.34). In the P600 time-window, a significant main effect of Violation was observed: F (1, 23) = 5.67, p = .03, $\eta_p^2 = .20$, with the targets in the semantic-violation condition evoking more positive amplitudes (M = 1.32, SD = 0.50) than the targets in the control condition (M = -0.05, SD = 0.26).

In the analysis of syntactic violations, we found no evidence for processing costs in the N400 time-window (M (Violation) = -0.26, SD = 0.31 vs. M (No Violation) = 0.08,

SD = 0.38), F (1, 23) = 8.82, p = .01, η_p^2 = .28. In the P600 time-window, on the other hand, we found a significant main effect of Violation: F (1, 23) = 24.73, p < .001, η_p^2 = .52, with the targets in the syntactic-violation condition evoking more positive amplitudes (*M* (Violation) = 2.28, *SD* = 0.52) than the targets in the control condition (*M* (No Violation) = -0.05, *SD* = 0.26). There was additionally a significant Violation by Electrode Region interaction, F (2, 42) = 3.91, p = .03, η_p^2 = .15, with the difference in the magnitude of the P600 effect being the greatest over the central (*M* (Violation) = 2.52, *SD* = 0.60 vs. *M* (No Violation) = -0.30, *SD* = 0.32) and parietal (*M* (Violation) = 2.22, *SD* = 0.53 vs. *M* (No Violation) = -0.49, *SD* = 0.32) electrode sites.

To conclude, semantic and syntactic violations produced the expected effects. Semantic violations resulted in both an N400 and a P600 effect, consistent with many prior ERP studies (e.g., Frenzel, Schlesewsky, & Bornkessel-Schlesewsky, 2011; Kuperberg, 2007; Kutas & Federmeier, 2011; Van de Meerendonk, Kolk, Vissers, & Chwilla, 2010; Van Petten & Luka, 2012). And syntactic violations resulted in a P600 effect, in line with prior work (Frederici, Hahne & Saddy, 2002; Kaan, Harris, Gibson, & Holcomb, 2000; Osterhout & Holcomb, 1992, 1993). Thus our materials robustly elicit the well-established effects, and our participants show sensitivity to linguistic structure. We now proceed to examine the critical presupposition violation condition.

3.2. Presupposition Processing

In the analysis of presupposition violations, the mean amplitudes of ERPs evoked by target word (*again*) in the control and presupposition-violation conditions (see (6.a,b) above) were entered as the dependent variable in the repeated measures ANOVA. As in the analyses of semantic and syntactic violations, the independent factors were Violation

(Absent vs. Present), Electrode Region (Anterior vs. Central vs. Posterior vs. Occipital), and Lateralization (Left vs. Midline vs. Right). All repeated measures for the within factors used the Greenhouse - Geisser correction. Figure 3 shows the waveforms evoked in response to the target word *again* in the presupposition-violation and control conditions. Based on the visual examination of the evoked brainwaves and of the modulation of the mean global field power (MGFP) of the ERP amplitudes, a positive-going component was identified in the 300-750 ms time-window. Magnitudes of ERP responses were examined in the 300-450 ms time-window, where an early positivity has been observed in prior ERP studies (the P3b component; Debener, Makeig, Delorme, & Engel, 2005; Dien, Spencer, & Donchin, 2004), and in the 450-750 ms time-window, a period of the late positivity in the ERP responses (the P600 component).

The amplitudes of ERP responses to the word *again* were more positive in the presupposition-violation condition than in the control condition in both the early P3b time-window ($M = 1.66$, $SD = .28$; $M = 0.99$, $SD = .27$; $F\,(1, 23) = 4.96$, $p = .04$, $\eta_p^2 = .18$), and in the late P600 time-window ($M = 1.15$, $SD = .31$; $M = 0.19$, $SD = .32$; $F\,(1, 23) = 9.46$, $p = .01$, $\eta_p^2 = .29$). None of the interactions were significant in either time-window (all $Fs < 1.45$).

Thus, the violation of temporal presupposition was associated with a positive deflection in the early P3b and the late P600 time-windows. This pattern is distinct from the earlier reported – and replicated here – patterns of ERPs elicited by semantic violations (a bi-phasic N400/P600 pattern) and syntactic violations (a P600 pattern), suggesting that neurocognitive mechanisms of presupposition processing differ from those of basic semantic or syntactic processing. The observed extended positivity in

response to temporal presupposition violation also stands in contrast to the earlier reported bi-phasic N400/P600 pattern evoked by the violation of the uniqueness presupposition (Kirsten et al., 2014), implying some heterogeneity in the processing of different types of presupposition (Karttunen, 1971,1973).

4. Discussion

The goal of the present study was to examine the time-course of temporal presupposition processing triggered by the word *again*. The results revealed an extended positivity that starts as early as 300 ms post the onset of *again* and lasting through the standard P600 time-window (450 – 750 ms).

The positivity observed in the early time-window (300 – 450 ms) is reminiscent of the P3b component, which is often detected in response to novel, unpredictable stimuli that disconfirm participants' expectations (Debener, Makeig, Delorme, & Engel, 2005; Dien, Spencer, & Donchin, 2004; Donchin, 1981; Friedman, Cycowicz, & Gaeta, 2001; Goldstein, Spencer, & Donchin, 2002). The P3b has been proposed to reflect revisions to one's mental model of the conversation/environment (Donchin & Coles, 1988). The process of mental model updating/revision has been associated with an increased demand for attentional resources (Donchin & Coles, 1988; Polich, 2007).

The positivity observed in the late time-window (450 – 750 ms) is typically labeled as the P600 component. As discussed in the Introduction, the P600 was initially detected in response to words that did not fit with the preceding syntactic context (Hagoort, Brown, & Groothusen, 1993; Osterhout & Holcomb, 1992) and was taken to reflect syntactic processing. Over the years, this interpretation of the P600 component has been challenged. For example, some studies have reported ERP patterns resembling the

syntactic P600 in response to semantic violations (e.g., Kolk, Chwilla, Van Herten, & Oor, 2003; Kim & Osterhout, 2005; Kuperberg, Kreher, Sitnikova, Caplan, & Holcomb, 2007). Based on this evidence, some have suggested that the P600 reflects cognitive processes of discourse reanalysis and updating of mental discourse models (Brower, Fitz, & Hoeks, 2012; Kolk & Chwilla, 2007; Kuperberg, 2007; O'Rourke & Van Petten, 2011) or error correction processes within a noisy comprehension system (Fedorenko et al., submitted). Similar to the P3b, the P600 has also been proposed to reflect generic attention reorientation processes (Sassenhagen & Bornkessel-Schlesewsky, 2015).

Thus, the P3b and the P600 components – at least under some interpretations – reflect similar cognitive processes, including the updating of mental discourse models and attention reorientation (Brower et al., 2012; Donchin & Coles, 1988; Sassenhagen & Bornkessel-Schlesewsky, 2015). In fact, some have argued that these two components belong to the same family and should be referred to as the P3b/P600 complex (e.g., Coulson, King, & Kutas, 1998; Gunter, Stowe, & Mulder, 1997; Sassenhagen, Schlesewsky, & Bornkessel-Schlesewsky, 2014; cf. Frisch, Kotz, von Cramon, & Friederici, 2003; Osterhout, 1999). Under this interpretation, the ERP effects that we observed for presupposition violations correspond to a single extended P3b/P600 component. This component plausibly reflects integrative processes of reorganization and updating of the mental discourse representation based on the prior context with information provided by a presupposition trigger.

Alternatively, the observed pattern can be thought of as consisting of two separate, albeit related, components, each associated with a specific function in presupposition processing. In particular, the P3b could reflect the detection of a disparity

between the mental representation formed by the preceding context and the presupposition trigger, and the P600 could be associated with the potential resolution of the earlier identified incongruence. This kind of an interpretation of the P3b-P600 pattern has been previously advanced in ERP studies that examined the processing of anaphoric expressions (Li & Zhou, 2010), omitted stimuli (Nakano, Rosario, Oshima-Takane, Pierce, & Tate, 2014), and garden-path sentences (Friederici, Mecklinger, Spencer, Steinhauer, & Donchin, 2001). Interestingly, in cases of violation of pragmatic inference where resolution of incongruence is impossible or extremely effortful, a sustained negativity rather than positivity has been reported (Leuthold, Filik, Murphy, & Mackenzie, 2012; Politzer-Ahles, Fiorentino, Jiang, & Zhou, 2013; Zhao, Liu, Chen, & Chen, 2015), suggesting variability in cognitive mechanisms of pragmatic inference.

Regardless of whether the observed ERP patterns evoked during temporal presupposition processing correspond to a monophasic P3b/P600 or a biphasic P3b-P600, the positivity identified here was registered much earlier than in the study of the uniqueness presupposition processing in German by Kirsten et al. (2014). In that study, presupposition-violating trigger words elicited greater positivity (compared to triggers that did not violate presuppositions) only after 500 ms post trigger-word onset. In the earlier 300-450 ms time-window, violations of uniqueness presuppositions were associated with an increased negativity. Thus, our observation of an extended positivity associated with presupposition processing stands in contrast to the finding of a biphasic N400/P600 ERP pattern reported by Kirsten et al. (2014). The discrepancy between the two studies might reflect differences in the cognitive mechanisms of temporal versus uniqueness presupposition processing. In the case of the uniqueness presupposition, as in

(10), the word *the* presupposes that there was a single bear in the zoo, but also triggers a reference to this unique object mentioned previously in the context:

(10) *Tina was in the zoo and saw a polar bear. She observed that* ***the*** *polar bear was aggressive*.

The process of establishing references in contexts has been examined extensively in prior ERP research (e.g., Anderson & Holcomb, 2005; Barkley, Kluender, & Kutas, 2015; Heine, Tamm, Hofmann, Hutzler, & Jacobs, 2006; Van Berkum, Brown, Hagoort, & Zwitserlood, 2003; van Berkum, 2004; Van Berkum, Koornneef, Otten, & Nieuwland, 2007). In most of these studies, researchers manipulated the number of candidate referents provided in the context for a definite noun phrase. In (11.a), for example, there is a single unique referent for the target *the girl*, whereas in (11.b) *the girl* might refer to either of the two girls mentioned in the context:

(11.a) *David had asked the boy and the girl to clean up their room …. David told* ***the girl*** *that had been on the phone to hang up.*

(11.b) *David had asked the two girls to clean up their room …. David told* ***the girl*** *that had been on the phone to hang up.*

Resolving referential ambiguities, as in (11.b), has been shown to give rise to a widely distributed negative deflection starting at 300 ms after the onset of the definite noun phrase and labeled the "Nref" (Van Berkum et al., 2003; Van Berkum, 2004; Van Berkum et al., 2007). Van Berkum and colleagues demonstrated that the Nref is elicited only in contexts where referential ambiguity needs to be resolved. In contexts like (11.c), where no candidate referents are given for the definite noun phrase and, hence, referential failure takes place, no Nref was observed:

(11.c) *David had asked the two boys to clean up their room …. David told* ***the girl*** *that had been on the phone to hang up.*

In Kirsten et al. (2014), the presupposition violation condition (12) was characterized by referential ambiguity:

(12) *Tina was in the zoo and saw some polar bears. She observed that* ***the*** *polar bear was aggressive.*

The polar bear could refer to any of the bears in the zoo. Resolving this ambiguity could have led to the negative deflection observed in the 300-450 ms time-window, which was plausibly an Nref effect rather than a semantic N400, as it was described by Kirsten et al. (2014). In our study, we did not observe an Nref effect because our presupposition violation contexts (13) contained no candidate referents for the trigger word *again* (i.e., there was no recently activated memory token of Jake tipping a maid). From the point of view of referential processing then, our materials were most similar to cases like (11.c) above where no Nref effect was reported.

(13) *Jake had never tipped a maid at the hotel before. Today he tipped a maid at the hotel* ***again****, although the hotel paid its maids good wages.*

The temporal presupposition violations that we investigated here evoked different ERP patterns from the uniqueness presupposition violations that Kirsten et al. (2014) investigated. This result suggests that different cognitive mechanisms might be at play during the processing of these two types of presuppositions, in line with some theoretical proposals (Abusch, 2005, 2009; Jayez et al., 2015; Romoli, 2015). Further empirical examination of similarities and differences in the patterns of ERPs evoked during the processing of different types of presuppositions is needed. An important consideration for

this future work is that presupposition triggers vary in whether they entail their presuppositions. While it has been suggested that the trigger *again* does not entail its presupposition, many other triggers are known to do so (Sudo 2012). As a result, the experimental tasks in future studies of presupposition will need to be carefully designed in order to isolate the processing of presupposition from the processing of entailment. Our study provides evidence that presupposition triggers are heterogeneous in nature and require different processing mechanisms.

5. Conclusions

Using ERPs, we here investigated the on-line processing of temporal presuppositions (in particular, presuppositions triggered by the word *again*). Violations of the presupposition associated with *again* in English evoked a positivity, which spanned the extended time-window of 300 – 750 ms, most plausibly corresponding to the P3b/600 complex (Coulson, King, & Kutas, 1998; Gunter, Stowe, & Mulder, 1997; Sassenhagen, Schlesewsky, & Bornkessel-Schlesewsky, 2014). This result provides evidence for rapid, on-line integration of presupposed content triggered by the adverb *again* and contextual information. The observed pattern contrasts with previous work on the processing of presuppositions associated with definite articles in German (Kirsten et al., 2014), where a bi-phasic N400/P600 was reported. Future work will investigate whether these different patterns reflect differences in the representation and processing of different presupposition triggers.

Footnotes:

[1] The studies by Kirsten et al. (2014) and Hertrich et al. (2015) were conducted in German. The cited examples are English translations of stimuli. In this example, the definite determiner “the” in the second sentence presupposes an existence of a single, unique item (one particular polar bear). This presupposition is in direct conflict with the background knowledge set up by the first sentence that describes existence of several, similar items (some polar bears).

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Figure 1. Grand average ERP responses to the semantically expected (black thick lines) versus unexpected (red thin lines) target words. The x-axis shows time (in ms) from the onset of the presentation of the target word, and the y-axis shows voltages (in μV).

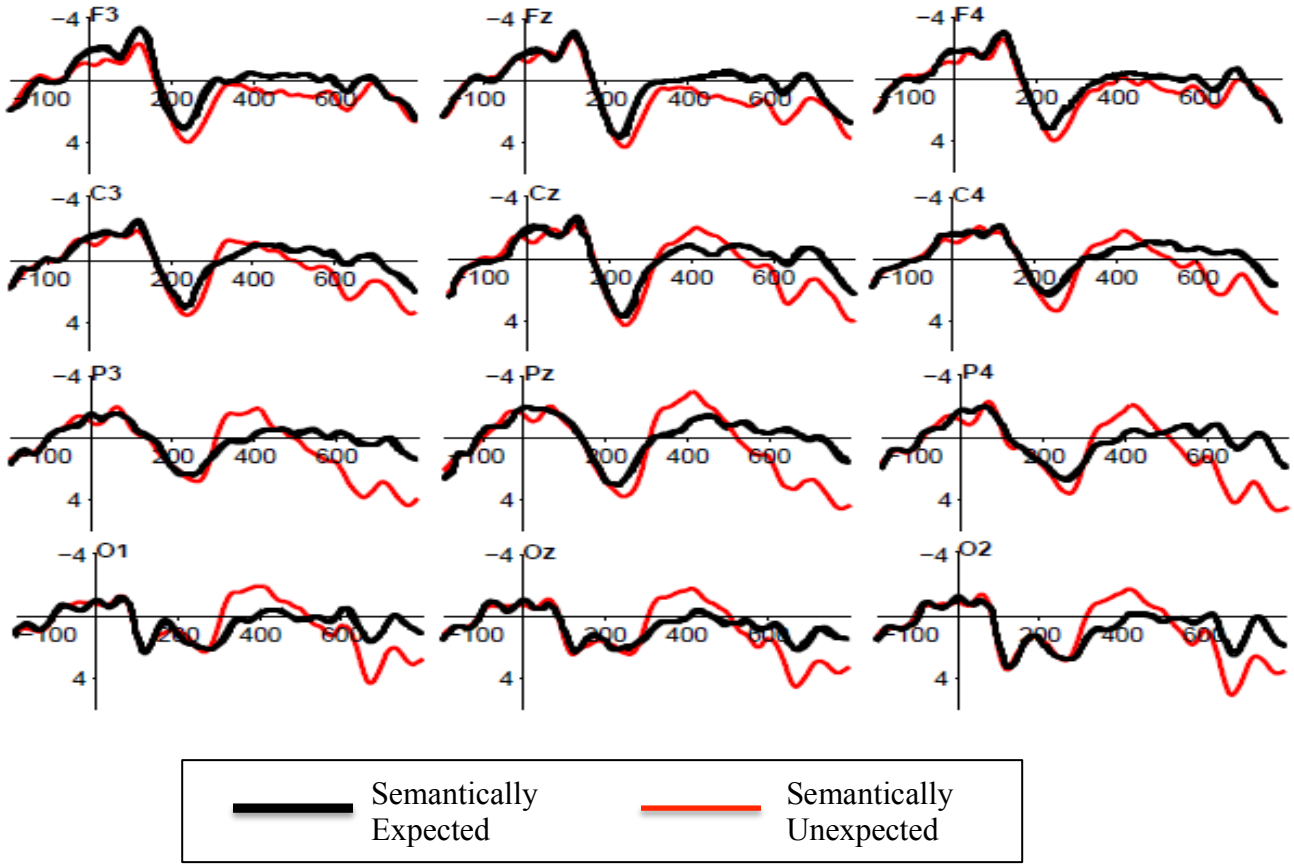

Figure 2. Grand average ERP responses to the syntactically expected (black thick lines) versus unexpected (red thin lines) target words. The x-axis shows time (in ms) from the onset of the presentation of the target word, and the y-axis shows voltages (in μV).

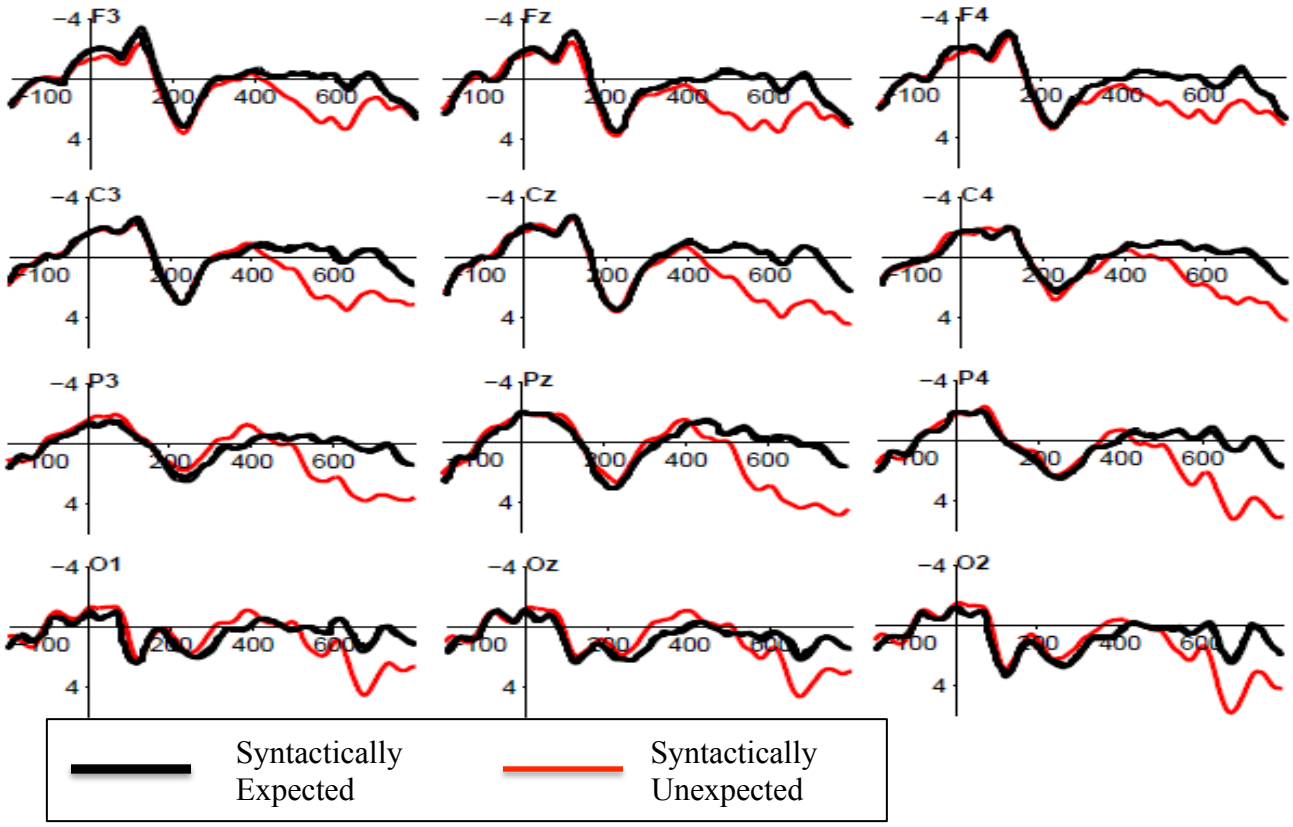

Figure 3. Grand average ERP responses to the temporal presupposition trigger *again* in the control context with no violations (black thick lines) vs. in the context with presupposition violation (red thick lines). The x-axis shows time (in ms) from the onset of the presentation of the word *again*, and the y-axis shows voltages (in μV).