

# Verb aspect, event structure, and coreferential processing



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Abstract

We used an offline story continuation task and an online ERP reading task to investigate coreference processing following sentences that portrayed transfer-of-possession events as either ongoing or completed using imperfective and perfective verb aspect (e.g., Amanda was shifting/shifted some poker chips to Scott.). The story continuation task demonstrated that people were more likely to begin continuations with references to the Goal than to the Source, but that perfective aspect strengthened this bias. In the ERP task we probed expectations for Source and Goal participants by employing pronouns that matched one of the participants in gender. The ERP results were consistent with the biases revealed in the story completion task and demonstrate that the difference in Goal bias for the two forms of aspect were manifested differently in the brain. These results provide novel behavioral and neurocognitive insight into how verb aspect influences the construction of situation models during language comprehension.

Keywords: verb aspect, thematic roles, coreferential processing, pronouns, ERP

# Verb Aspect, Event Structure, and Coreferential Processing

It is well known that the process of understanding language involves the construction of a mental model of the situations being described (Johnson-Laird, 1983; Kintsch, 1988; Morrow, Greenspan, & Bower, 1987; Sanford & Garrod, 1981; van Dijk & Kintsch, 1983; Zwaan, Langston, & Graesser, 1995; for a review see Zwaan & Radvansky, 1998). This mental model is a reflection of dynamic processes that underlie the combination of different types of linguistic (e.g., phonetic, morphosyntactic, semantic), and nonlinguistic (world knowledge, situational environment) representations. One of the crucial facts about successful mental model construction, and thus successful language understanding, is that comprehenders have to know which situations, people, objects, and locations are referred to in their models from the linguistic cues provided by language. In this regard, the lexical and semantic properties of verbs play a key role in constraining people's expectations for who and what the continuing discourse is likely to be about (e.g., Altmann & Kamide, 1999; 2007; Arnold, 2001; Ferretti, Kutas, & McRae; 2007; Hare, McRae, & Elman, 2003; Kamide, Altmann, & Haywood, 2003; Stevenson, Crawley, & Kleinman, 1994; Van Berkum, Koornneef, Otten, & Nieuwland, 2007). In the present research we examine how describing situations as ongoing versus completed, achieved by varying verb aspect, influences people's expectations about who will be mentioned next as the discourse continues and, importantly, how these expectations influence the ease or difficulty people have during pronoun interpretation. Relatively little is known about how temporally describing situations as ongoing or as completed influences referential processing, despite the importance of referential processing for successful language understanding, and despite the fact that psycholinguistic studies of verb aspect have demonstrated that this linguistic cue profiles

participants, objects, and locations differently in the temporal and causal structure of situations (Ferretti et al., 2007; Madden & Zwaan, 2003; Morrow, 1985; Truitt & Zwaan, 1997).

*Verb Aspect and Language Processing*

The grammatical category of verb aspect functions as a morphosyntactic cue that signals to comprehenders how to view the temporal unfolding of situations mentioned in linguistic environments. In the present research, we examine two different forms of aspect, including the imperfective (*was giving*) and perfective (*gave*). Imperfective aspect provides a temporal focus on the ongoing development of situations, whereas the perfective aspect describes the entire situation as completed (Comrie, 1976; Moens & Steedman, 1988).

Previous psycholinguistic investigations have shown that verb aspect constrains situation model construction in different ways (for a review see Madden & Ferretti (in press)). First, aspect contributes to the determination of how information in a text is partitioned with respect to foreground and background (Carreiras, Carriedo, Alonso, & Fernandez, 1997; Madden & Zwaan, 2003; Magliano & Schleich, 2000; Morrow, 1985). For example, Magliano and Schleich had people read narratives in which a critical situation was either described as ongoing with imperfective aspect (*was delivering*) or as completed with perfective aspect (*delivered*). These sentences were always followed by three additional sentences that were consistent with being concurrent or subsequent to the critical situation. Activation of the critical situation in people's mental models of the text was probed by measuring the time it took them to verify whether a situation denoted by a verb phrase appeared earlier in the text (e.g., *deliver baby*). The verb phrases were presented either immediately after the critical sentence or after three subsequent sentences. Their results demonstrated that at the end of the critical sentence and after three

subsequent sentences, people were faster to identify the verb phrases that had appeared earlier in the text when they originally appeared in imperfective versus perfective form.

A second way that verb aspect influences the construction of situation models is by modulating the activation of participants, instruments, and locations of situations (Carreiras et al., 1997; Ferretti, Kutas, & McRae, 2007; Morrow, 1985; Truitt & Zwaan, 1997). For example, Morrow (1985) had people first memorize a layout of a house and then read sentences describing the movement of a person from one room (source room) to another room in the house (goal room). These sentences always involved verbs of motion and were inflected with either imperfective or perfective aspect (e.g., John was walking/walked from the kitchen to the bedroom). Morrow found that following imperfective sentences, people located the figure (i.e., John) somewhere on the path between the source room and goal locations, whereas following perfective aspect people consistently located the figure in the goal room. More recently, Ferretti et al. (2007) have extended these findings by showing that verb aspect also plays a role in the activation of world knowledge about the common locations of situations. Specifically, they demonstrated in a semantic priming task and in online sentence comprehension that knowledge about common locations of situations is more activated following verbs marked with imperfective than perfective aspect.

These results suggest that the ongoing versus completed status of situations signaled by different verb aspects has important implications for how salient people, objects, and locations are situated in the mental models that people construct during language processing. However, to date there has been relatively little research examining how modulation of the activation of the different properties of situations by verb aspect influences coreferential processing. This is somewhat surprising as in order for successful language comprehension to occur, people need to

know which individuals are being referred to in their mental model. The ability of verb aspect to focus on the different temporal components of situations suggests that this linguistic device should have consequences during coreferential processing. For example, resolving the referents for pronouns may be less difficult when they are coreferential with nouns that have been made more accessible as a result of the temporal focusing properties of verb aspect.

A recent offline study by Rohde, Kehler, and Elman (2006) provides evidence for how verb aspect influences coreferential processing. Participants in this study read context sentences that included verbs of transfer presented in either perfective or imperfective form, followed by an ambiguous pronoun that could be used to refer to either the Source or Goal participant (see Example 1). Participants were asked to generate natural sentence continuations using the pronoun prompt provided.

(1) $\text{John}_{\text{SOURCE}}$ handed / was handing a book to $\text{Bob}_{\text{GOAL}}$. He _____.

Judges annotated the elicited continuations, assessing whether the continuation was consistent with a Goal interpretation of the pronoun (Goal continuation) or a Source interpretation (Source continuation). The results demonstrate that people were significantly more likely to generate a Goal continuation following a context sentence with perfective aspect than one with imperfective aspect.[1]

[1] Rohde et al. also predicted that the end-state bias would emerge primarily when the passage completions were related by a certain *coherence relation*, in particular the Occasion relation, the definition of which explicitly encodes a bias towards the end state of the previous event. This prediction was also confirmed: passages related by Occasion showed a strong Goal bias, whereas the next two most common coherence relations (Explanation and Elaboration) – which we would expect to have different event-structural focusing properties – actually exhibited a Source bias. This result provides further support for the role of event structure in pronoun interpretation.

The effect of verbal aspect on coreference was confirmed in a second study by Rohde and Kehler (2008) that manipulated both verbal aspect and prompt type (see Examples 2 and 3) in order to show that patterns of pronoun interpretation fit within a more general model of people's expectations regarding who will be mentioned next as a discourse continues. The second study replicated the original pronoun interpretation results in the pronoun-prompt condition, and it also showed that verbal aspect influences people's choice of next mention in a bare-prompt condition.

(2) [pronoun prompt] John$_{SOURCE}$ handed / was handing a book to Bob$_{GOAL}$. He _____.

(3) [bare prompt] John$_{SOURCE}$ handed / was handing a book to Bob$_{GOAL}$. _____.

Verbal aspect had the same effect in both prompt conditions (more Goal continuations following perfective context sentences than following imperfective context sentences), though there were more Goal continuations overall in the bare-prompt condition than in the pronoun-prompt condition. This difference was due to the prevalence of bare-prompt continuations that contained proper name references to the Goal. Following previous researchers (Stevenson et al. 1994, Arnold 2001), Rohde and Kehler suggest that the pronoun-prompt data exhibit the results of two interacting biases: A bias regarding choice of next mention, which favors the Goal and is influenced by aspectual form, and a bias regarding choice of referring expression, which reflects a general tendency to use pronouns to corefer with grammatical subjects (i.e., the Source referent in contexts like (1-3)). Taken together, these two biases explain both the reduced number of Goal continuations in the pronoun-prompt condition and the consistent increase in the number of Goal continuations following context sentences with perfective aspect, regardless of prompt type.

Rohde et al.'s results are also important because they help differentiate between alternative explanations for previous research that similarly show that the frequency of Goal completions often rivals or exceeds Source completions following verbs of transfer (e.g., Arnold, 2001; Stevenson et al., 1994; Stevenson et al., 2000). Stevenson et al. (1994), for example, considered two explanations for their observed Goal bias: a thematic-role-level heuristic that ranks Goals above Sources and an event-structural bias toward focusing on the end state of a previously described event, under the assumption that Goals are typically more salient to the end state of a transfer-of-possession event than Sources. Consistent with Stevenson et al.'s (1994) event-structual bias, Rohde et al.'s results demonstrate that focusing on the end state versus the ongoing development of these events modulated the proportion of Source and Goal completions, despite the fact that the thematic roles and their fillers were kept constant across conditions.

*The Present Study*

Rohde et al.'s research demonstrates that using verb aspect to focus on the different temporal components of events can influence people's expectations about which participant is likely to be mentioned next, and thus influence the interpretation of ambiguous pronouns. The present study was designed to further this research in two specific ways. First, we use an online reading task to examine how the temporal structure of transfer-of-possession events affects people's expectations about which individual will be mentioned next. In order to examine whether the coreferential processes identified by Rohde et al. are also found when people simply read for comprehension, we used event-related brain potential methodology (ERP). The use of ERP allows us to examine people's brain potentials for pronouns that unambiguously refer to either the Source or Goal when the pronoun is more or less consistent with their expectations about which participant is likely to be mentioned next. This methodology is also particularly

well-suited for investigating referential processing in the brain because of its fine temporal resolution and because people can simply read for comprehension without a secondary task. Furthermore, past research has used ERP methodology to examine how people interpret pronouns during language processing, and thus provides a foundation for interpreting the results of the present experiments (we discuss this past research in the introduction to Experiment 2).

Second, we also conducted an offline story continuation task, in which people read transfer-of-possession context sentences and then generated follow-ons that naturally continued the story. However, unlike Rohde et al. (2006) and Rohde and Kehler (2008), we used a context sentence containing two opposite-gendered participants. This allowed us to index people's expectations regarding which participant was likely to be mentioned next, as well as analyze the choice of referring expressions in a context in which pronominal references would be unambiguous. This manipulation was important for providing for a measure of how expected reference to the Source and Goal are at the point in which pronouns were presented in the online ERP reading task.

Our main prediction for the following experiments is as follows. Under the plausible assumption that Goals are more salient than Sources within the end state of transfer-of-possession events, we expect to find more continuations that mention the Goal in the perfective case than in the imperfective case. Accordingly, we likewise predict that brain potentials during pronoun interpretation in such passages should also reflect this aspect-modulated Goal bias.

## Experiment 1

We conducted a story continuation experiment to test how the representation of the temporal structure of an event affects comprehenders' expectations about which individual will be mentioned next. Event structure was manipulated by changing the aspect of the verb in the

context sentence. We evaluated next-mention biases in participants' elicited story continuations and tested for effects of verbal aspect.

*Participants*

54 undergraduate psychology students from Wilfrid Laurier University participated in the experiment for course credit. All participants were monolingual native English speakers.

*Materials*

The stimuli consisted of 72 target items and 72 fillers. Target items contained a context sentence with a Source-Goal transfer-of-possession verb. The Source and Goal referents were both proper names that differed in gender.

(2) Perfective: $\text{John}_{\text{SOURCE}}$ handed a book to $\text{Mary}_{\text{GOAL}}$. _____.

(3) Imperfective: $\text{John}_{\text{SOURCE}}$ was handing a book to $\text{Mary}_{\text{GOAL}}$. _____.

Gender was balanced across stimuli. Each participant saw half the verbs with perfective aspect and half with imperfective, and no participant saw any verb more than once. The 72 target items were randomly mixed with the 72 fillers. The fillers described non-transfer-of-possession events involving one or two individuals. Half of the filler verbs were perfective and half were imperfective. The majority of perfective verbs used active voice and a small minority used passive voice. As in the target items, the individuals were mentioned using proper names. There were 10 randomly ordered lists.

*Task*

Story continuations were collected via a web-based interface that participants could access from their own computer. Each item was presented on a page by itself with a text box in which participants were instructed to write their continuation. The entire experiment took roughly forty-five minutes, but participants were encouraged to have an hour available so that the experiment could be completed in one session.

Participants were instructed to imagine a natural story continuation for each prompt, writing the first continuation that came to mind and avoiding humor. In this task, participants create a mental model of the event in the matrix clause and then write a continuation that reflects their expectations about where the story is going. As such, the task involves both interpretation and production.

*Evaluation and Analysis*

The elicited story continuations were coded for several factors: choice of first mention (Source or Goal), referring expression of first mention (name or pronoun), and position of first mention (first word or not).

Analyses of variance were conducted on the first-mention choices to test for an effect of aspect. One-sample t-tests were used to compare the percentages of first mentions to a hypothetical mean of 50%. Because the assessed first mention choices represent two binary outcomes, the results are treated as proportions. Therefore, an arcsine transformation was first applied to the percentages of first mentions before carrying out analyses of variance and t-tests. For clarity of presentation, we present means in the form of raw proportions.

## Results

The continuations from 14 participants were eliminated because the participants misunderstood the task (writing only sentence fragments or questions) or did not complete the entire experiment. From the remaining participants' continuations ($N = 2880$), 13% were excluded because the continuation did not contain any reference to either the Source or the Goal (or else referred to the Source and Goal together as "they"), along with 3.6% that consisted only of a sentence fragment (e.g., a prepositional phrase or a relative clause), 3.4% that referred to the Source or Goal only with a possessive ("his" or "hers"), and less than 1% that were nonsensical or contained mistakes concerning the interpreted gender of the male/female names.

Our analysis is restricted to continuations in which either the Source or Goal was mentioned as the first word of the continuation ($N = 1859$) and the subset of those in which the reference to the Source or Goal was pronominalized ($N = 912$).[2] As Figure 1 shows, both the perfective and imperfective conditions yielded a bias to the Goal, but the strength of the Goal bias differed by verbal aspect.

Considering only the first-mention references regardless of referring expression ($N = 1859$), Goal references made up a large majority of the responses following both perfective context sentences (85.7%; $t_1(39) = 13.10$, $p < 0.001$; $t_2(71) = 17.71$, $p < 0.001$) and imperfective context sentences (77.0%; $t_1(38) = 9.29$, $p < 0.001$; $t_2(71) = 11.88$, $p < 0.001$). However, Goal references were significantly more common following perfective than imperfective verbs ($F_1(1,38) = 18.76$, $p < 0.001$; $F_2(1,71) = 9.97$, $p < 0.003$).

[2] Note that we report the analysis for the first word of the continuations because that is the critical point of interest in the ERP study reported in Experiment 2. However, the results were similar for the pattern of first-mention preferences regardless of position of mention ($N = 2263$): the Goal bias was stronger following perfective sentences (83.7%; $t_1(39) = 12.35$, $p < .001$; $t_2(71) = 16.11$, $p < .001$) than following imperfective sentences (77.2%; $t_1(39) = 9.54$, $p < .001$; $t_2(71 = 12.21$, $p < .001$). Goal references were significantly more common following perfective context sentences than imperfective sentences ($F_1(1,39) = 23.09$, $p < .001$; $F_2(1, 71) = 11.39$, $p < .002$).

The results were similar for the pronominal first-mention references ($N = 912$): the Goal bias was stronger following perfective sentences (75.7%; $t_1(35) = 6.19, p < 0.001$; $t_2(71) = 7.90, p < 0.001$) than following imperfective sentences (57.0%; significant only by items: $t_1(33)=1.38, p < 0.18$; $t_2(71) = 4.64, p < 0.001$). Goal references were significantly more common following perfective context sentences than imperfective sentences ($F_1(1,32) = 16.51, p < 0.001$; $F_2(1,71) = 6.86, p < 0.011$).[3]

## Discussion

The results of Experiment 1 demonstrated that the number of Goal continuations that people write increases following context sentences with perfective aspect as opposed to imperfective aspect. We found that, across both verb aspects, people were more likely to write continuations that began with a reference to the Goal participant, but that the Goal bias was even stronger in the perfective condition. This result is consistent with findings in previous work showing that verb aspect influences coreferential processing (Rohde et al. 2006; Rohde & Kehler, 2008). It also fits earlier claims based on perfective-only materials that the Goal bias is driven by a preference to focus on the end state of a transfer-of-possession event since the Goal is presumably more salient than the Source with respect to the end state (Arnold 2001; Stevenson et al. 1994). As would be expected on this view, the salience of the Goal is comparatively reduced in the imperfective condition, in which the context sentence event is portrayed as ongoing.

Like Rohde et al. 2006, we find that the effect of verbal aspect is also apparent when we consider only the subset of the data in which the Source or Goal was referred to with a pronoun. Rohde et al.'s results were different in one respect, however, in that the Goal continuations in the pronoun-only data in that work made up less than half of the continuations following context

[3] Not all subjects contributed data to the subset of the data we analyzed. Therefore the degrees of freedom do not always reflect 40 subjects and 72 items.

sentences in both aspect conditions. This difference was anticipated, however, in light of the fact that pronouns in our stimuli (unlike Rohde et al.) were unambiguous. As with studies before them (Stevenson et al. 1994, Arnold 2001), Rohde and Kehler (2008) found a large bias toward the Goal when all referring expressions were catalogued in a bare-prompt condition like the one used here; the effect of providing a pronoun prompt in an ambiguous context diminished this bias. In the current experiment, providing an *unambiguous* context brought the Goal bias for pronouns closer to what has been previously witnessed for referring expressions in bare-prompt conditions. Accordingly, a greater percentage of pronouns was also witnessed in this experiment than was found in these previous studies, reflecting a greater willingness to use a pronoun in an unambiguous context. Indeed, pronominal references to both the Source and Goal were quite common in both conditions in the story continuation experiment, which was important in confirming the naturalness of the stimuli used in the experiment described in the next section.

## Experiment 2

The main goal of Experiment 2 was to use ERP methodology to investigate how verb aspect interacts with the lexical semantic structure of transfer-of-possession verbs to constrain expectations about who is likely to be mentioned next during online language comprehension. People read sentences describing either ongoing or completed transfer-of-possession events followed by sentences that always described a plausible subsequent event. Importantly, the second sentences always began with a pronoun that unambiguously referred to either the Source or Goal participant in the prior sentences. Using unambiguous pronouns enabled us to probe the event participant that is most expected by examining the electrophysiological response when the references are more or less consistent with these expectations.

(4) Sue$_{(SOURCE)}$ handed/was handing a timecard to Fred$_{(GOAL)}$. She/He asked about the upcoming meeting.

The two brain potentials that have figured most prominently in research examining pronoun interpretation include the P600 (sometimes also called syntactic positive shift), and the left anterior negativity (LAN). The P600 is a positive brain potential that peaks at approximately 600 ms following the onset of a word and can begin as early as 200 ms (Federmeier, Kluender, & Kutas, 2003). This component is known for being sensitive to syntactic violations (Coulson et al., 1998; Friederici, Hahne, & Saddy, 2002; Hagoort, Brown, & Groothusen, 1993; Osterhout & Holcomb, 1992), syntactic complexity (Kaan, Harris, Gibson, & Holcomb, 2000; Osterhout & Holcomb, 1992), and syntactic reanalysis (Friederici et al., 2002; Schmitt, Bernadette, Lamers, & Munte, 2002). The P600 usually is maximal at central and posterior head locations when elicited to syntactic violations (e.g., Coulson et al., 1998; Osterhout & Mobley, 1995) and syntactic

complexity (Kaan et al., 2000; Kaan & Swaab, 2003). Alternatively the P600 has been shown to have a more frontal distribution as a result of resolving syntactic ambiguities toward nonpreferred structures (Kaan & Swaab, 2003; Hagoort, Brown, & Osterhout, 1999; Osterhout & Holcomb, 1992).

The second component of interest is the left anterior negativity (or LAN) which typically appears between 300-500 ms following the onset of eliciting stimuli (Kluender & Kutas, 1993; Munte, Heinze, & Mangun, 1993; Osterhout & Holcomb, 1992), although the LAN has also been observed with onsets as early as 100-200 ms (e.g., Friederici, Pfeifer, & Hahne, 1993). The LAN is elicited to morphosyntactic violations and word category violations (Friederici et al., 1993; Coulson et al., 1998; Osterhout & Holcomb, 1992) and increased working memory load (Coulson et al., 1998; Kluender & Kutas, 1993; King & Kutas, 1995). In research involving morphosyntactic violations, LANs have been observed when there are violations of gender, case marking, number, and verb agreement (Coulson et al., 1998; Hagoort & Brown, 1994; Munte et al., 1993), and often appear in conjunction with P600s (e.g., Coulson et al., 1998).

Previous ERP research has also demonstrated that P600s and sometimes anterior negativities are elicited as a consequence of people's expectations for upcoming discourse to refer to a gender specific participant (and thus a gender specific pronoun) under conditions in which there are no formal morphosyntactic violations (e.g., Nieuwland & Van Berkum, 2006; Osterhout & Mobley, 1995; Van Berkum et al., 2007). For example, Osterhout and Mobley (1995) examined gender agreement mismatches between personal pronouns and potential subject antecedents that were inherently male or female (e.g., *The aunt heard that she/he had won the lottery*). In these sentences readers could take the mismatching pronoun as referring to some unmentioned entity rather than the subject of the sentence and thus there is no syntactic violation

per se. Their results demonstrated a P600 that was maximal at central and posterior head locations for pronouns with a gender that mismatched the subject antecedents relative to when they matched. Furthermore, mismatching pronouns elicited greater negativity than matching pronouns at anterior head locations between 300-500 ms following their onsets. These results have been taken to suggest that people's expectations for the sentence to continue to refer to the subject influenced their likelihood of taking the pronouns as coreferential with the subject, and that this in turn led to a electrophysiological response that was consistent with the typical response following a morphosyntactic violation.

A more recent study by Van Berkum, Koornneef, Otten, and Nieuwland (2007) used ERP to examine how the implicit causality of verbs influences the foregrounding of participants and thus subsequent coreferential processing with respect to those participants. Prior research with this class of verbs has demonstrated that people typically expect a discourse to continue with references to participants that are implicated in the causes of such events (e.g., Au, 1986; Brown & Fish, 1983; Garvey & Caramazza, 1974; McKoon, Greene, & Ratcliff, 1993). In Van Berkum et al. (2007), people read passages such as (5), which included verbs with a strong bias for the first noun phrase to be associated with the cause of the event, followed by pronouns that unambiguously referred to participants that were either consistent (5a) or inconsistent (5b) with this bias. Note that Van Berkum et al.'s passages also did not involve a morphosyntactic violation, as their passages always contained an available gender matching antecedent.

(5a)
David and Linda were both driving pretty fast. At a busy intersection they crashed hard into each other. David apologized to Linda because he according to the witnesses was the one to blame.

(5b)

David and Linda were both driving pretty fast. At a busy intersection they crashed hard into each other. Linda apologized to David because he according to the witnesses was not the one to blame.

Van Berkum et al.'s results demonstrated that relative to bias consistent pronouns, bias inconsistent pronouns elicited a P600 at central and parietal locations between 400-700 ms following their onset. The authors suggest that this occurred as a result of people proactively predicting that the remainder of the sentence is about the participant that is consistent with the implicit bias of the verb and the P600 occurs when they encounter a pronoun that has a gender that does not match this prediction.

Based on the ERP research reviewed above and the results of Experiment 1, we expect the present study to find a P600 and/or possible anterior negativity that demonstrates that people expect a pronoun to be coreferential with the Goal participant following verbs of transfer for both forms of verb aspect and, importantly, that this Goal bias should be greater following perfective than imperfective sentences.

## Method

### *Participants*

Fifty-two undergraduate psychology students from Wilfrid Laurier University participated for course credit. All participants were native English speaking, had normal or corrected-to normal visual acuity, and all were right-handed. None of the students participated in Experiment 1.

### *Materials*

The same 72 target and 72 filler passages used in Experiment 1 were used in Experiment 2. The 72 target passages were placed across 4 lists and each list contained 18 passages from each

of the four experimental conditions (perfective verb / Source pronoun, perfective verb / Goal pronoun, imperfective verb / Source pronoun, imperfective verb / Goal pronoun). The same 72 filler passages appeared in each list. No participant saw any verb more than once, and across the 4 lists each verb was paired with each of the four experimental conditions.

*Procedure*

Participants sat in a chair in front of a computer monitor located in an electrically-shielded chamber. They were instructed to read the words one at a time for comprehension and to answer periodic comprehension questions by pressing buttons labeled "Yes" and "No". The 72 experimental passages and 72 filler passages were presented one word at a time in the center of a computer screen. All words were presented for a duration of 300 ms with an SOA of 500 ms. The interval between the offset of the last word of the first sentence and the onset of the first word of the second sentence (i.e., the target pronouns) was 1000 ms.

*EEG Recording and Analysis*. The electroencephalogram (EEG) was recorded from 64 electrodes distributed evenly over the scalp (see Figure 1 for a schematic diagram of electrode array). Eye movements and blinks were monitored via additional electrodes placed on the outer canthus and infraorbital ridge of each eye. Electrode impedances were kept below 5KΩ. EEG was processed through a Neuroscan Synamps2 amplifier set at a bandpass of 0.05 - 100 Hz, and was digitized at 250 Hz.

## Results

Data was re-referenced off-line to the average of the left and right mastoids. High frequency noise was removed by applying a low-pass filter set at 30 Hz. ERPs were then computed in epochs that extended 100 ms before the pronouns to 1000 ms after their onset. Trials

contaminated by blinks, eye-movements, and excessive muscle activity were rejected off-line before averaging; a total of 12% of trials were lost due to such artifacts.

Figure 3 illustrates the results following perfective sentences. Pronouns with Source referents elicited brain potentials that were more negative at left anterior locations than pronouns with Goal referents, a difference that began early - approximately 100-300 ms following the onset of the pronoun, and was sustained throughout much of the 1000 ms epoch. Source co-referential pronouns also elicited greater positivity than Goal referring pronouns at central and posterior head locations; this difference was maximal between 500-800 ms post stimulus onset. Figure 4 shows the results following imperfective sentences. As in the perfective condition, Source pronouns also elicited greater anterior negativity than Goal pronouns, but this effect had a broader distribution and a later onset (approximately 300 ms post stimulus onset) than in the perfective condition. Over central and posterior locations, Source and Goal referring pronouns did not vary in amplitude, unlike their perfective sentence counterparts.

In order to capture these differences at anterior versus central and posterior head locations, we conducted one three-way ANOVA on the mean amplitudes for anterior electrodes (FP1, FPZ, FP2, AF3, AF4, F7, F5, F3, F1, FZ, F2, F4, F6, F8, FT7, FC5, FC3, FC1, FCZ, FC2, FC4, FC6, FT8) and a second ANOVA on central and posterior electrodes (T7, C5, C3, C1, CZ, C2, C4, C6, T8, TP7, CP5, CP3, CP1, CPZ, CP2, CP4, CP6, TP8, P7, P5, P3, P1, PZ, P2, P4, P6, P8, P07, P05, PO3, P0Z, P04, P06, PO8, CB1, O1, OZ, O2, CB2). These two analyses were conducted on 3 temporal regions of interest: 100-300 ms, 300-500 ms, and 500-800 ms. In all analyses, the primary factors of interest were aspect (imperfective vs. perfective), reference (Goal vs Source) and electrode site, all of which were within-participants variables. List was used as a between participant factor to stabilize variance caused by rotating participants across different lists. We

followed up all significant three-way interactions found between aspect, reference, and electrodes at anterior locations by conducting an additional topographic distribution analysis with all electrodes down the midline removed, and with hemisphere (left hemisphere electrodes (FP1, AF3, F7, F5, F3, F1, FT7, FC5, FC3, FC1) versus right hemisphere electrodes (FP2, AF4, F8, F6, F4, F2, FT8, FC6, FC4, FC2)) added as a within participant variable. All p-values are reported after epsilon correction (Huynh-Felt) for repeated measures with greater than one degree of freedom.

*100 - 300 ms*

*Anterior*. The main effects of aspect and reference were nonsignificant, both $F$s < 1.27, and the two-way interaction between aspect and reference also did not reach significance, $F(1, 48) = 1.90$, $p > .17$. However, planned comparisons revealed that mean amplitudes for Source referring pronouns ($M$ = -.67 microvolts) were more negative than for Goal referring pronouns ($M$ = -.04 microvolts) following perfective sentences, $F(1, 48) = 4.13$, $p < .05$. Alternatively, Source and Goal referring pronouns did not vary in amplitude following imperfective sentences (Source, $M$ = -.54 microvolts; Goal, $M$ = -.52 microvolts), $F < 1$.

There was also a three-way interaction between aspect, reference, and electrode site, $F(22, 1056) = 3.02$, $p < .05$. We followed up this interaction by conducting the aforementioned analysis with hemisphere added as an independent variable. The three-way interaction between aspect, reference, and hemisphere was marginally significant, $F(1, 48) = 3.61$, $p < .07$. Following perfective sentences, mean amplitudes for Source pronouns ($M$ = -.92 microvolts) were more negative than Goal pronouns ($M$ = .05 microvolts) over left hemisphere electrodes, $F(1, 48) = 15.72$, $p < .001$, whereas the difference between the Source and Goal pronouns over right

hemisphere electrodes was nonsignificant (Source, $M$ = -.40 microvolts; Goal, $M$ = -.04 microvolts), $F < 1$. Alternatively, the reference of the pronouns following imperfective sentences had no influence on amplitudes over the left (Source, $M$ = -.47 microvolts; Goal, $M$ = -.61 microvolts) or right hemisphere locations (Source, $M$ = -.60 microvolts; Goal, $M$ = -.41 microvolts), both $Fs < 1$.

*Central + Posterior*. All effects were nonsignificant.

*300 - 500 ms*

*Anterior*. In this region, there was a marginal effect of reference which occurred because Source-referring pronouns had amplitudes that were more negative than Goal-referring pronouns (Source, $M$ = -2.73 microvolts; Goal, $M$ = -2.14 microvolts), $F(1, 48) = 3.63$, $p < .07$. The two-way interaction between aspect and reference was not significant, $F< 1$. The difference in amplitudes between Source and Goal pronouns was marginally significant following imperfective sentences (Source, $M$ = -2.72 microvolts; Goal, $M$ = -2.01 microvolts), $F(1, 48) = 3.20$, $p < .08$, but did not approach significance following perfective sentences (Source, $M$ = -2.75 microvolts; Goal, $M$ = -2.26 microvolts), $F(1, 48) = 1.53$, $p = .22$.

Similar to the 100-300 ms region, there was a three-way interaction between aspect, reference, and electrode site, $F(22, 1056) = 3.02$, $p < .05$. The results of the distribution analysis demonstrated a significant three-way interaction between aspect, reference, and hemisphere, $F(1, 48) = 4.15$, $p < .05$. Following perfective sentences, mean amplitudes for Source pronouns were more negative than Goal pronouns over left hemisphere electrodes (Source, $M$ = -3.08 microvolts; Goal, $M$ = -2.15 microvolts), $F(1, 48) = 9.00$, $p < .01$, whereas there was no difference between the pronouns over right hemisphere electrodes (Source, $M$ = -2.23 microvolts;

Goal, $M$ = -2.18 microvolts), $F < 1$. In contrast, following imperfective sentences, mean amplitudes for Source pronouns were significantly more negative than Goal pronouns over right hemisphere electrodes (Source, $M$ = -2.63 microvolts; Goal, $M$ = -1.73), $F(1, 48) = 8.53$, $p < .01$, and marginally different over left hemisphere electrodes (Source, $M$ = -2.61 microvolts; Goal, $M$ = -2.08 microvolts), $F(1, 48) = 2.82$, $p < .10$. Thus, greater anterior negativity for Source than Goal pronouns was found following both imperfective and perfective sentences, although this difference was more localized to the left hemisphere following perfective sentences.

*Central + Posterior*. At these electrode sites there was a marginal crossover interaction between aspect and reference, $F(1, 48) = 3.55$, $p < .07$. At central and posterior sites, mean amplitudes for Source pronouns are more positive than Goal pronouns following perfective sentences (Source, $M$ = 1.69 microvolts; Goal, $M$ = 1.18 microvolts), whereas following imperfective sentences, Source pronouns were less positive than Goal pronouns (Source, $M$ = 1.24 microvolts; Goal, $M$ = 1.67 microvolts). Although these differences in amplitudes between pronouns for the two types of aspect led to the marginal interaction between aspect and reference, the differences in amplitudes did not reach significance following imperfective sentences, $F(1, 48) = 1.50$, $p = .23$, or perfective sentences, $F(1, 48) = 2.07$, $p = .16$. The three-way interaction between aspect, reference, and electrode site was nonsignificant.

*500 - 800 ms*

*Anterior*. Reference continued to have an influence in this later time region as mean amplitudes for Source pronouns were more negative than for Goal pronouns (Source, $M$ = -1.24 microvolts; Goal, $M$ = -.42 microvolts), $F(1, 48) = 5.35$, $p < .03$. The difference in amplitude between the two pronouns was significant following imperfective sentences (Source, $M$ = -1.24

microvolts; Goal, $M$ = -.16 microvolts), $F(1, 48) = 5.26$, $p < .03$, but did not approach significance when they followed perfective sentences (Source, $M$ = -1.24 microvolts; Goal, $M$ = -.69 microvolts), $F(1, 48) = 1.45$, $p > .23$. The two-way interaction between aspect and reference was not significant, $F < 1$. However, there was once again a significant three-way interaction between aspect, reference, and electrode site, $F(22, 1056) = 2.57$, $p < .05$. The distribution analysis demonstrated a marginal three-way interaction between aspect, reference, and hemisphere, $F(1, 48) = 3.81$, $p < .06$. This interaction occurred because mean amplitudes were more negative for Source pronouns than for Goal pronouns following imperfective sentences at left hemisphere electrodes (Source, $M$ = -1.07 microvolts; Goal, $M$ = -.091 microvolts), $F(1, 48) = 13.52$, $p < .001$, and right hemisphere locations (Source, $M$ = -1.25 microvolts; Goal, $M$ = -.08 microvolts), $F(1, 48) = 19.36$, $p < .001$. Alternatively, amplitudes for Source pronouns were more negative than for Goal pronouns following perfective sentences over left hemisphere electrodes (Source, $M$ = -1.54 microvolts; Goal, $M$ = -.58 microvolts), $F(1, 48) = 13.17$, $p < .001$, but not over right hemisphere electrodes (Source, $M$ = -.81 microvolts; Goal, $M$ = -.69 microvolts), $F < 1$.

*Central + Posterior*. There were no significant main effects of aspect or reference at central and posterior electrodes, both $F$s < 1.32. However, there was a significant two-way interaction between aspect and reference, $F(1, 48) = 5.66$, $p < .03$. This interaction occurred because mean amplitudes were significantly more positive for Source than Goal pronouns following perfective sentences (Source, $M$ = .91 microvolts; Goal, $M$ = .06 microvolts), $F(1, 48) = 6.39$, $p < .02$, whereas the difference between Source and Goal pronouns following imperfective sentences was nonsignificant (Source, $M$ = .38 microvolts; Goal, $M$ = .67

microvolts), $F < 1$. The three-way interaction between aspect, reference, and electrode site was nonsignificant.

## Discussion

The results of Experiment 2 demonstrated that people had more difficulty integrating the pronouns when they referred to Source participants as opposed to Goal participants, following both imperfective and perfective verbs of transfer. Specifically, greater anterior negativity was observed to Source than Goal pronouns for both forms of aspect. However, the distribution of this negativity was different for the two forms of verb aspect – following perfective sentences, the negativity had an earlier onset (100-300 ms) and was focal over the left hemisphere, whereas following imperfective sentences the negativity had a later onset (300-500 ms) and a broader distribution. Furthermore, following perfective verbs only, the left anterior negativity was followed by a P600 to Source coreferential pronouns at central and posterior locations. This effect began at approximately 300 ms and was maximal between 500-800 ms.

The differences observed between the two forms of verb aspect are informative about the relative difficulty people have when encountering pronouns that refer to the Source participant. As discussed above, the pattern of anterior negativity followed by a central/posterior P600 has previously been found in pronoun studies in which there are morphosyntactic violations (e.g., Coulson et al., 1998; Osterhout & Mobley, 1995). Furthermore, research investigating mismatches between gender expectations and pronouns when there are no formal morphosyntactic violations have also demonstrated the presence of a P600 (Osterhout & Mobley, 1995; Van Berkum et al., 2007; Nieuwland & Van Berkum, 2006), and sometimes this P600 is preceded by greater anterior negativity that is also elicited to the mismatching pronoun

(Osterhout & Mobley, 1995). Our pattern of findings for pronouns coreferential with Source participants following perfective verbs are consistent with this research, and suggest that readers in the present study are treating the gender mismatch as a morphosyntactic problem under conditions in which there is a potential antecedent with a matching gender.

These results are consistent with Van Berkum et al.'s (2007) referential attractor proposal for the appearance of P600s during referential processing when there are no morphosyntactic violations. Under this approach, strong biases from context (e.g., implicit biases of verbs, gender specific names, gender role stereotypes) can lead people to proactively predict that upcoming discourse is likely to refer to a specific referent. These strong preferences (or attractors) for participants can lead to P600s when the morphosyntactic features of an encountered pronoun mismatch the gender of the participant that is foregrounded in a comprehender's situation model, even when there are alternative participants in the context that are gender consistent. Applied to the present research, this approach would suggest that the strong goal bias found following perfective verbs foregrounds the Goal participant in a comprehender's situation model, whereas the Source participant is backgrounded and less available for coreferential processing. Thus, when people encountered a pronoun with morphological features that were inconsistent with this strong Goal bias, they treat the mismatch as a morphosyntactic problem.

The pattern of results for pronouns that followed imperfective verbs was not completely expected. We expected that the same general pattern observed in the perfective condition would also be observed to some degree in the imperfective condition, but that the differences in amplitudes between the Source and Goal referring pronouns would be less (i.e., smaller LAN followed by a smaller P600). However, the timing and topographical differences between the anterior negativities for the two forms of aspect, in conjunction with the absence of the P600 in

only the imperfective condition, show that the brain construes the gender mismatch differently for the two forms of verb aspect. For the perfective condition it appears as though a morphosyntactic problem has occurred, whereas the imperfect condition seems to show referential integration difficulty without construing the difficulty as morphosyntactic in nature.

Other recent research by Van Berkum and colleagues provides additional insight into our pattern of findings (Nieuwland & Van Berkum, 2006; Nieuwland, Otten, & Van Berkum, 2007). Of particular interest is their research demonstrating a broadly distributed anterior negativity that is elicited to pronouns and nouns that are consistent with multiple antecedents with the same gender. This referentially induced sustained negativity, dubbed the Nref effect, begins approximately 300 ms post stimulus onset and does not appear in conjunction with P600s. Importantly for the present research, the size of the Nref effect is modulated by the implicit biases of verbs to be followed by particular participants mentioned in sentences (Nieuwland & Van Berkum, 2006). For example, Nieuwland and Van Berkum (2006) conducted a referential cloze task in which they noted how often people complete sentence fragments by using the ambiguous pronouns to refer to either the first participant or second participant mentioned in the fragments (e.g., Linda invited Anna when her…). They then examined their observed Nref effect as a function of verbs that were highly biased toward a specific participant versus those that had similar biases for both participants. This analysis demonstrated that the Nref effect for ambiguous pronouns was much larger when the verbs exhibited similar biases toward both participants as opposed to a high bias toward one participant. This result suggests the Nref effect may be most apparent under conditions in which the lexical semantic properties of the verbs do not lead to large differences in the foregrounding of multiple referential candidates in a comprehender's situation model. Furthermore, the results also demonstrate that the brain does

not treat such referential ambiguity in the same manner as a morphosyntactic problem (or anomaly) as no P600 is elicited.

In the present experiment we examined unambiguous pronouns, so one might wonder how our results relate to these findings other than the fact that the Nref effect resembles our anterior negativity following imperfective verbs in both timing and topography. Recall, however, that the results of Experiment 1 demonstrated that perfective verbs had a significantly stronger bias to be followed by first mentions to the Goal participant than did imperfective verbs, especially when pronouns were used (Perfective Goal completions: 75.7%, Imperfective Goal completions: 57%). Thus the focus on the ongoing development of transfer-of-possession events by imperfective aspect functions to make the Source participant foregrounded to a greater degree in a comprehender's situation model than when the events are described as completed. One possibility is that the anterior negativity in the imperfective condition reflects difficulty in referential processing due to the fact that both Source and Goal participants are simultaneously active in the developing situation model. When people receive a pronoun that is consistent with the less preferred but still referentially available Source participant, it creates referential processing difficulty leading to the observed anterior negativity and the absence of a P600.

## General Discussion

The present research shows that verb aspect interacts with the lexical semantic properties of verbs of transfer to influence a comprehender's expectations for who is likely to be mentioned next as a discourse proceeds. This finding adds to a growing body of literature that shows that describing situations as ongoing or completed with verb aspect influences the foregrounding and backgrounding of information (people, places, and objects) about those situations (Carreiras et al., 1997; Ferretti et al., 2007; Madden & Zwaan, 2003; Magliano & Schleich, 2000; Morrow, 1985; Rohde et al., 2006). Importantly, our ERP results extend this research by showing how the foregrounding and backgrounding of participants with verb aspect influences coreferential processing when people simply read sentences for comprehension. In addition, our offline story completion results provided an independent index for how likely pronouns were to refer to one participant or another in a comprehender's mental model, and the first mentioned biases revealed in that study were consistent with the pattern of results observed in the online ERP experiment.

Our findings also have implications for our understanding of the constraints that modulate the implicit biases of verbs with respect to the expectations they engender about which participants are likely to be mentioned next (Arnold, 2001; Stevenson et al., 1994; Rohde et al., 2006; Van Berkum et al., 2007). The results are consistent with previous research by Stevenson et al. (1994), Arnold (2001), and Rohde et al. (2006) in demonstrating that the Goal bias following verbs of transfer is an epiphenomenon of a bias toward focusing on the end state of the previously described event. Both the story completion data and ERP data demonstrated that focusing on the ongoing development of these situations reduced the bias toward the Goal participant in favor of the Source participant. Our results extend previous research by providing evidence that this event-level bias is also present during online language comprehension.

Our results also have implications for our understanding of how the brain deals with difficulty in coreferential processing that arises from these factors (e.g., Nieuwland & Van Berkum, 2006; Van Berkum et al., 2007). The present research demonstrates that the implicit biases associated with transfer of possession verbs also influences the ease in which people resolve the referents for pronouns and, crucially, that these biases are influenced by the temporal focus afforded by verb aspect. Our results for the perfective condition are consistent with recent research showing that the brain construes mismatches between strong gender expectations and pronouns as a morphosyntactic problem, even when the discourse contexts contain potential antecedents with matching gender (Osterhout & Mobley, 1995; Van Berkum et al., 2007). The lack of a P600 and the timing and topographic distribution of the anterior negativity observed for Source referents in the imperfective condition show that the brain does not treat the gender mismatch as a morphosyntactic problem, but rather as integration difficulty that is similar to the Nref effect found for pronouns that have genders that are consistent with multiple antecedents (Nieuwland & Van Berkum, 2006). Although more research is needed to clarify the relationship between our broadly distributed anterior negativity and the Nref component identified by Van Berkum and colleagues, our results show that a very similar negativity is also elicited for unambiguous pronouns.

Finally, our results are most consistent with constraint-based models (Garnsey, Pearlmutter, Myers, & Lotocky, 1997; MacDonald, Pearlmutter, & Seidenberg, 1994; McRae, Spivey-Knowlton, & Tanenhaus, 1998; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995) and other recent expectation-based approaches to sentence processing (e.g., Hale, 1991; Van Berkum et al., 2007; Levy, in press) that suggest that comprehenders simultaneously integrate information about how words combine to form the syntactic structure of a sentence

along with semantic, pragmatic, and real-world knowledge about the structure of events previously described in the discourse when interpreting discourse-dependent linguistic forms such as pronouns. The results reported here extend previous approaches by showing that verb aspect influences coreferential processing and, therefore, models of coreference (and models of sentence processing in general) need to incorporate information about the temporal and causal structure of (and real-world knowledge associated with) events to properly account for the data.

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Table 1

*Experiment 2 Grand Average (n = 52) results for each of the 3 time regions of interest at anterior and central/posterior scalp locations.*

| | F-values | | |
|---|---|---|---|
| | 100-300 ms | 300-500 ms | 500-800 ms |
| *Anterior* | | | |
| Aspect | .57 | .22 | .68 |
| Reference | 1.27 | 3.63 | 5.35* |
| Aspect x Ref | 1.90 | .15 | .67 |
| Aspect x Ref x Elec | 3.02* | 3.48* | 2.57* |
| *Central / Posterior* | | | |
| Aspect | .01 | .01 | .02 |
| Reference | .06 | .03 | 1.32 |
| Aspect x Ref | 1.92 | 3.55 | 5.66* |
| Aspect x Ref x Elec | 1.95 | 1.28 | 1.36 |

* $p < .05$

*Figure 1*. Next-mention biases by verbal aspect (with standard errors)

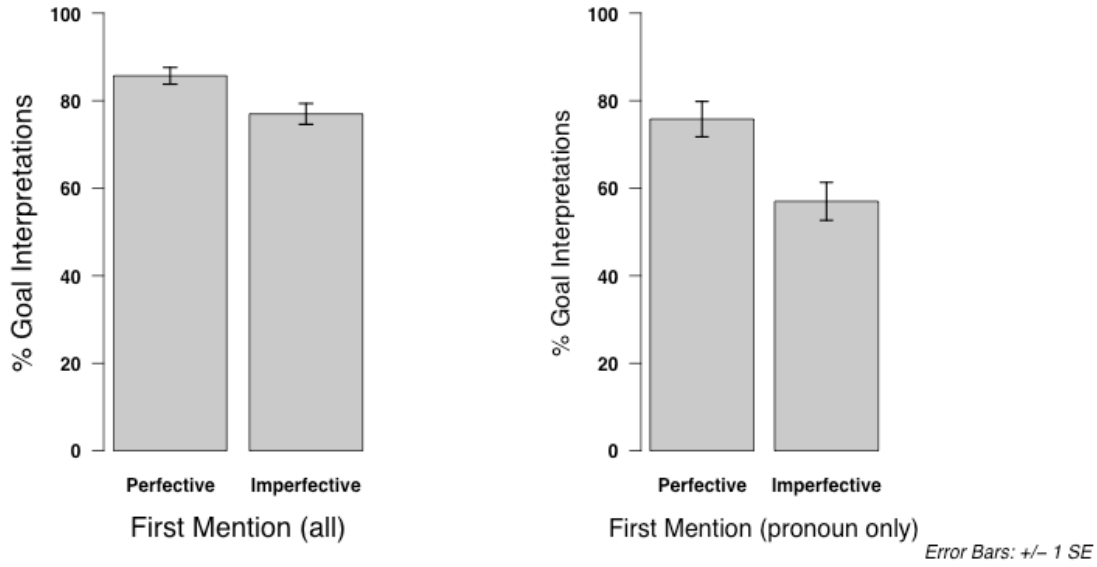


*Figure 2*. Schematic diagram showing the electrode labels and sites for the 64 channel electrode caps used in Experiment 2.

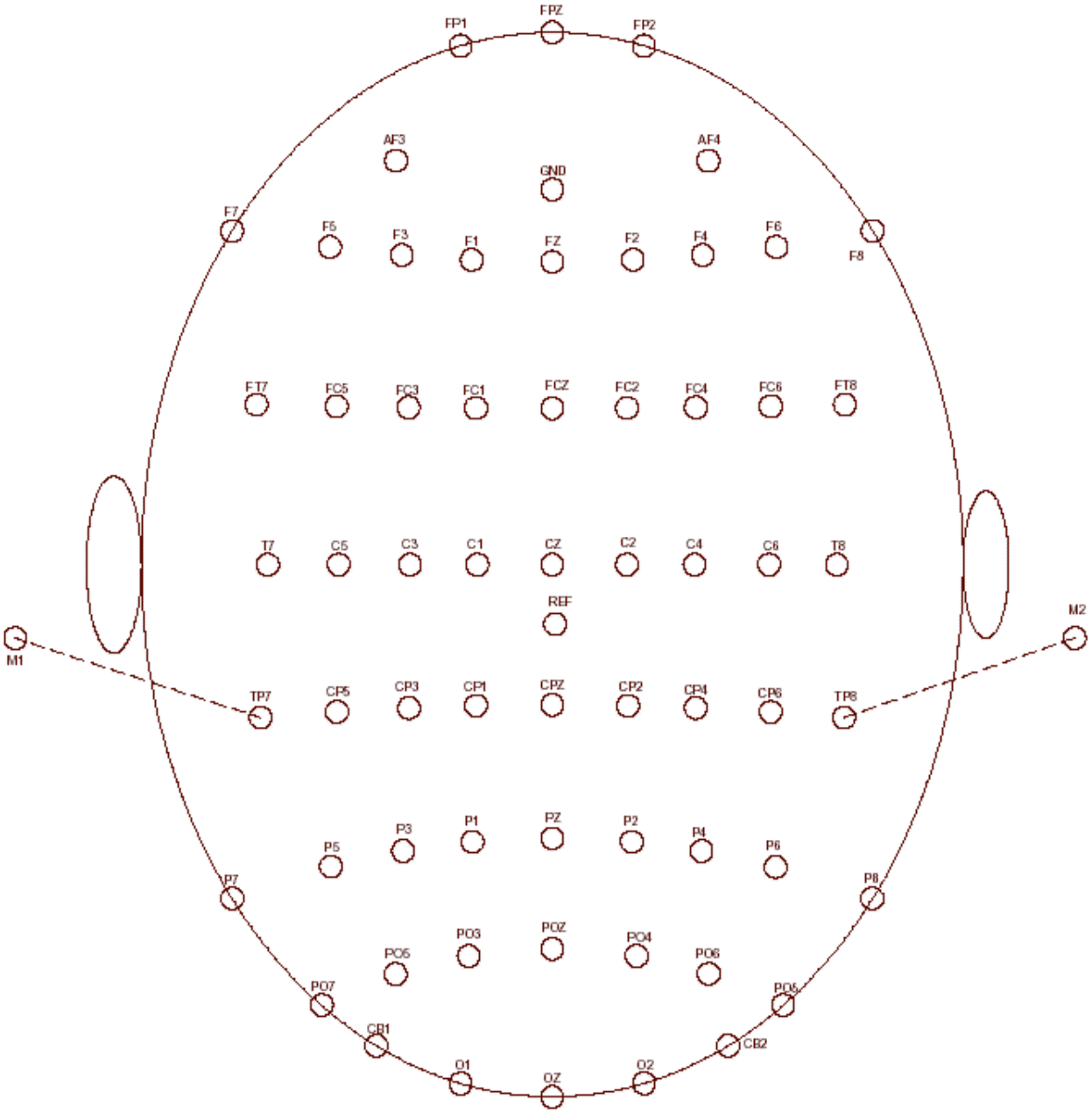
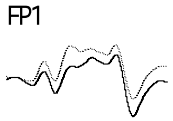


*Figure 3*. Grand average ($n$ = 52) results for source referring pronouns (dotted lines) and goal referring pronouns (solid lines) following perfective sentences at selected electrode sites.




Goal
Source

-2 μV

1 s

*Figure 4*. Grand average ($n$ = 52) results for source referring pronouns (dotted lines) and goal referring pronouns (solid lines) following imperfective sentences.