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## The brain, verbs, and the past: Neurolinguistic studies on time reference

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## Summary

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Agrammatic aphasia is a language disorder due to brain damage, in which grammar is particularly impaired. A core issue in neurolinguistic research is to what extent the language problems that people with aphasia suffer are exclusive to their brain damage. Possibly, the processes that are vulnerable in aphasia also require more cognitive resources for the healthy brain. A way to tap into unimpaired language processing is to study event-related potentials (ERPs) registered at the scalp. ERPs are brain responses that can be related to different levels of linguistic processing, including grammar. Also eye-movements can be used to study brain responses to language, given that gazes are drawn to objects in a closely time-locked manner with what is being heard (Cooper, 1974). In this thesis, the neural correlates of time reference expressed by verbs were investigated in aphasic and non-brain-damaged speakers of Dutch, German, and Russian using accuracy and reaction time measures, as well as ERP and eye-tracking.

Chapter 1 provided the theoretical background of the studies, leading to the research questions for the studies. Results from several structurally different languages demonstrated that agrammatic aphasic patients find it more difficult to produce and comprehend verb forms that refer to the past than verb forms that refer to the present, captured in the Past DIscourse LIinking Hypothesis (PADILIH; Bastiaanse et al., 2011). The PADILIH holds that verb forms referring to the past, such as ‘wrote’, are impaired in agrammatic aphasia, because they are discourse linked: in order to interpret past time reference, an additional link has to be made to some other event time in the discourse. Verb

forms referring to the present, such as ‘writes’, are relatively spared, because they are locally bound: no additional discourse-link is needed because the event time the verb refers to is in the here-and-now of the moment of speaking. The PADILIH is based on two assumptions: (1) Present tense is locally bound within the sentence and past tense is discourse linked (Zagona, 2003) and (2) Discourse linking is impaired in agrammatic aphasia, whereas local binding is intact (Avrutin, 2000). Discourse linking difficulties can also be observed in the pronominal domain (Edwards & Varlokosta, 2007; Grodzinsky et al., 1993; Ruigendijk et al., 2006) and in *wh* phrases (Avrutin, 2000). In healthy speakers similar patterns can be traced (Dragoy et al., 2012; Faroqi-Shah & Dickey, 2009; Jonkers et al., 2007). This PhD project was aimed at addressing some remaining issues with respect to time reference and discourse-linking:

1. Past time reference is discourse linked.
2. The PADILIH applies to language use in general.
3. Past time reference difficulties are irrespective of tense.
4. Processing verbs that refer to the past is delayed in agrammatism.

Chapter 2 aimed to (1) investigate whether discourse-linking is the common denominator of the deficits in time reference, *wh* questions, and object pronouns, and (2) to compare the comprehension of discourse-linked elements in people with agrammatic and fluent aphasia. Three sentence-picture-matching tasks were administered to 10 agrammatic, 10 fluent aphasic, and 10 non-brain-damaged Russian speakers: (1) the Test for Assessing Reference of Time (TART) for present imperfective (reference to present) and past perfective (reference to past), (2) the Wh Extraction Assessment Tool (WHEAT) for *which*- and *who*-subject questions, and (3) the Reflexive-Pronoun Test (RePro) for reflexive and pronominal reference. Non-brain-damaged speakers scored at ceiling and significantly higher than the aphasic participants. An overall effect of discourse-linking was found in the TART and WHEAT for the agrammatic speakers, and in all three tests for the fluent speakers. Scores on the RePro were at ceiling. The results are in line with the prediction that comprehension problems of individuals with agrammatic and fluent aphasia for sentences that contain verbs with past time reference, *which*-question words and pronouns, are caused by the fact that these elements involve discourse linking. The effect is not specific to agrammatism, although it may result from different underlying disorders in agrammatic and fluent aphasia.

Chapter 3 first aimed to untangle tense problems from problems with past time reference through verb morphology in people with aphasia. Time reference

does not always coincide with tense; in languages such as Dutch and English, reference to the past can be established by using past tense (e.g., ‘he wrote a letter’) or a present tense auxiliary in combination with a participle, i.e., the present perfect (e.g., ‘he has written a letter’). The second aim of this chapter was to compare the production of time reference inflection by people with agrammatic and fluent aphasia. A sentence completion task was used to elicit reference to the non-past and past in Dutch. Reference to the past was tested through (1) a simple verb in past tense and (2) a verb complex with an auxiliary in present tense + participle (the present perfect). Reference to the non-past was tested through a simple verb in present tense. Fourteen agrammatic aphasic speakers, sixteen fluent aphasic speakers and twenty non-brain-damaged speakers took part in this study. Non-brain-damaged speakers scored at ceiling and significantly higher than the aphasic participants. Agrammatic speakers performed worse than fluent speakers, but the pattern of performance in both aphasic groups was similar. Reference to the past through past tense and [present tense auxiliary + participle] was more impaired than reference to the non-past. An error analysis revealed differences between the two groups. People with agrammatic and fluent aphasia experience problems with expressing reference to the past through verb inflection. This past time reference deficit is irrespective of the tense employed. The error patterns between the two groups reveal different underlying problems.

In Chapter 4, an ERP study was presented that aimed to investigate time reference in the healthy brain. If the time frame (past, present, future) is set by a temporal adverb, the verb inflection should correspond (yesterday he walked; today he walks). Temporal violations by simple verbs (single, lexical verbs inflected with tense) in the present tense and with present time reference elicit a P600 effect (Dragoy et al., 2012; Baggio, 2008). However tense does not always coincide with time reference; in languages such as Dutch and English, reference to the past can be established by using the present tense in the present perfect (e.g., ‘he has eaten the cake’). The study in Chapter 4 investigated whether the P600 effects described by Dragoy et al. and Baggio were caused by tense or time reference violations of the verb. In the context of a past adverb, ERP responses to auxiliaries in present tense with either congruent past time reference or incongruent non-past time reference were compared. The findings showed that the P600 effect for violations of the temporal context was caused by the time reference of the complete verb form, rather than by the tense.

The goal of Chapter 5 was to (1) investigate whether differences exist between non-brain-damaged individuals and agrammatic aphasic individuals in correctly processing of future and past time reference inflection, and (2) enlighten the underlying mechanism of time reference comprehension failure by

agrammatic aphasic speakers. A visual-world experiment combining sentence-picture matching and eye-tracking was administered to 12 non-brain-damaged individuals and 6 agrammatic aphasic individuals, all native speakers of German. Participants heard German sentences with periphrastic future ('will + V') or periphrastic past ('has + V-d') verb forms while they were presented with pictures on a computer screen. Non-brain-damaged speakers scored at ceiling and significantly higher than the agrammatic aphasic speakers. The future condition was more difficult than the past condition for non-brain-damaged speakers (derived from response times) and agrammatic aphasic speakers (derived from response times and accuracy). However, eye movement patterns suggested a similar interpretation of future time reference in both groups, while agrammatic aphasic speakers showed a delay relative to non-brain-damaged speakers in interpretation of past time reference. The results support the PADILIH, because processing reference to the past in discourse syntax requires additional resources and, thus, is problematic and delayed for people with aphasia.

Chapter 6 concluded the dissertation with a general discussion and implications. The outcomes of the research contribute to the knowledge on the influence of discourse linking on past time reference assignment, compared to non-past time reference. This dissertation sheds light on how these types of time reference are represented in the brain, how they are processed and how they can be affected by brain damage. Individuals with agrammatic aphasia often omit or substitute (past) tense inflection. The knowledge on time reference acquired within this project adds to the understanding of the underlying deficits in aphasia, which is of importance for the development of assessment and treatment methods for individuals with aphasia. Chapter 6 concludes with some directions for further research.