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

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### Conclusions and further research directions

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The introduction of this dissertation described the background of the PADILIH (PAst DIscourse LInking Hypothesis; Bastiaanse et al., 2011). In the PADILIH, Bastiaanse et al. (2011) combine the theory on disturbed discourse syntax in agrammatic aphasia (Avrutin, 2000, 2006) with the idea that past tense is discourse-linked (based on Zagona, 2003, 2013). The hypothesis predicts 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 event in the past. Grammatical processing, including discourse syntax, is impaired in agrammatic aphasia. Verb forms that do not refer to the past, such as ‘writes’, are relatively spared: They do not require an additional discourse-link, because the event time the verb refers to is in the here-and-now of the moment of speaking.

This chapter contains an overarching discussion of the neurolinguistic studies on time reference morphology that were carried out using different offline and online, behavioral and physiological methodologies. In the next sections, the major findings will be discussed, and are followed by the implications of the results. The chapter concludes with directions for further studies.

## 6.1 Major conclusions

The introduction of this dissertation raised four issues, which formed the basis of the experiments discussed in the subsequent chapters. In the upcoming sections, the major conclusions of these experiments are discussed with respect to these issues.

### 6.1.1 Past time reference is discourse-linked

The first issue addressed in this dissertation is the claim that past time reference is problematic in aphasia because it is discourse-linked. This claim is an extension of Zagona's (2003, 2013) view that discourse-linking is required for past versus non-past tense, and Avrutin's assumption (2006) that processing by discourse syntax (which he argues to be necessary for tense in general) is problematic for aphasic individuals. This issue was tested in Russian in the experiment described in Chapter 2.

The rationale of the three-fold discourse-linking experiment in Chapter 2 was that, if past time reference is indeed discourse-linked, it should be similarly impaired in aphasia as other discourse-linked elements, such as *which* questions and object pronouns. Non-discourse-linked non-past time reference, *who* questions, and reflexives should be relatively spared. A three-fold comprehension study was carried out testing whether discourse-linking is the common denominator in the impairment patterns of these linguistic elements.

Experimental data of multiple types of discourse-linked elements within the same aphasic population were not yet available, because previous comprehension research in aphasia addressed different types of discourse-linked elements separately. Some studies showed that *which* questions are more impaired than *who* questions in agrammatism (Hickok & Avrutin, 1996; Neuhaus & Penke, 2008; Salis & Edwards, 2008), while other studies found no dissociation (in agrammatic aphasia: Kljajevic & Murasugi, 2010; Stavrakaki & Kouvava, 2003; in fluent aphasia: Wimmer, 2010). In the domain of pronominal anaphora, an impairment of comprehending object pronouns versus reflexives has been reported in agrammatism (Grodzinsky et al., 1993; Love, Nicol, Swinney, Hickok, & Zurif, 1998; Ruigendijk, Vasić, & Avrutin, 2006), although some studies reported equal impairment (Edwards & Varlokosta, 2007) or spared comprehension (Martínez-Ferreiro, 2010). No clear pattern emerged from studies in fluent aphasia (no impairment: Love et al., 1998; overall impairment: Ruigendijk &

Avrutin, 2003; pronoun processing worse than reflexive processing: Grodzinsky et al., 1993).

The three tests used in Chapter 2 were the Russian version of the TART (Bastiaanse et al., 2008) for time reference, the WHEAT for *wh*-questions, and the RePro for reflexives/pronouns. The results are in support of the claim that past time reference is discourse-linked. 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. Since the scores of the agrammatic speakers on the RePro were at ceiling, this test did not yield counter evidence. Therefore, it was concluded that the results support the prediction that problems that individuals with aphasia experience when comprehending 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 results are compatible with discourse-related processing differences between past and present tense that were demonstrated in the healthy brain (Dragoy, Stowe, Bos & Bastiaanse, 2012).

### 6.1.2 PADILIH applies to language use in general

The second issue addressed in this dissertation was the question whether the PADILIH (Bastiaanse et al., 2011) applies to language use in general, including processing by fluent aphasic and non-brain damaged individuals. The hypothesis was originally posed to explain data from agrammatic aphasia. This dissertation presented data from fluent aphasia and unimpaired language processing that can enlighten this issue.

The generalization of the PADILIH to fluent aphasia was investigated with the Russian discourse-linking comprehension tests in Chapter 2 and the Dutch time reference production test in Chapter 3, which included agrammatic and fluent aphasic speakers. The accuracy pattern of fluent aphasic individuals was similar to that of the agrammatic aphasic speakers. In comprehension, fluent aphasic speakers showed an overall impairment of discourse-linked elements, namely reference to the past, *which* questions, and object pronouns,<sup>1</sup> but not of non-past time reference, *who* questions, and reflexives. The Dutch TART study (Bos & Bastiaanse, 2008) showed that also in production, fluent aphasic individuals have similar error rates as agrammatic aphasic speakers on discourse-linked elements; however, this test revealed that the nature of the

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<sup>1</sup>Fluent aphasic speakers made, however, few errors on pronouns and reflexives.

errors is different. When agrammatic aphasic participants had to complete a sentence with a verb referring to the past and they made an error, they did not only substitute the verb form, but they also failed to retain the targeted reference to the past in their response. They often used non-past time reference or an infinitive. When fluent aphasic speakers made errors in the past time reference conditions, however, the majority of their errors contained the target time reference. Other studies also reported qualitatively different errors for agrammatic and fluent aphasic speakers (Dragoy & Bastiaanse, 2013; Jonkers & de Bruin, 2009; Kljajevic & Bastiaanse, 2011; Wiczorek, Huber, & Darkow, 2011).

A processing account such as the one by Caplan, Waters, DeDe, Michaud, and Reddy (2007) can explain the similar accuracy rates of fluent and agrammatic aphasic speakers. For both aphasic groups, discourse-linked elements require increased processing in discourse syntax, while non-discourse-linked elements require only narrow syntactic processing. In line with Caplan et al.'s theory (2007), the number of errors increased with computational load. However, the underlying disorder is different in these two aphasia types: As argued by Bastiaanse and Van Zonneveld (2004), agrammatic speakers have a functional deficit at the level of grammatical encoding (cf. Levelt, 1989), while fluent aphasic speakers have a functional deficit at the level of lexical retrieval. These different underlying disorders explain the differential error patterns in the production section of the Dutch TART, and why the impairment of past time reference has only been noted in everyday language of *agrammatic* aphasic speakers (Abuom & Bastiaanse; 2012; Beeke, Wilkinson, & Maxim, 2003; Simonsen & Lind, 2002; Stavrakaki & Kouvava, 2003). Agrammatic speakers have poor grammatical encoding abilities and additional grammatical processing (required for discourse-linked time reference) taxes this system even more (Avrutin, 2000, 2006). Fluent aphasic speakers have their main impairment in the phonological system and therefore do manage to produce the required time reference. However, discourse-linking also taxes their grammatical encoding, so they select a less complex verb form (with a non-finite lexical verb) with the target time reference.

Dragoy et al. (2012) argued that the PADILIH generalized to language processing by non-brain-damaged speakers, based on time reference violation data measuring reaction times (Dragoy et al., 2012; Farooqi-Shah & Dickey, 2009) and ERP responses (Baggio, 2008; Dragoy et al., 2012). The ERP experiment

described in Chapter 4 and in the eye-tracking experiment in Chapter 5 add further physiological data to this issue. The ERP experiment showed that the discourse-related effects in Dragoy et al. (2012) are caused by time reference, in line with the PADILIH. The results of the eye-tracking experiment, however, were not informative with respect to the difference between past and non-past time reference in non-brain-damaged individuals. The materials of the experiment turned out not to be suitable for testing the difference between past and non-past within a participant group, because a past picture bias in eye movements already appeared before the critical verbs conveying past or future time reference. The reaction times of the non-brain-damaged participants were reflecting this bias, such that no conclusions could be drawn on whether the time reference manipulation caused differential behavioral and physiological responses.

To conclude, the data reported in this dissertation together with previous data suggest that the PADILIH applies to how language is represented in the brains of both aphasic and non-brain-damaged individuals. In agrammatic aphasia, problems with past time reference are observable in spontaneous speech, on language tests, and during eye tracking. In fluent aphasia, the problems are less prominent in every day language, because these speakers are able to convey past time reference through less complex verb forms. The physiological responses of non-brain-damaged speakers reflect discourse-related differences between past and non-past time reference.

### 6.1.3 Past time reference difficulties irrespective of tense

The third issue raised in the Introduction in Chapter 1 concerned the difference between past tense and past time reference. In previous studies investigating time reference, tense and time reference could not be untangled. More specifically, previous studies with the TART (Bastiaanse, Jonkers, & Thompson, 2008) used the past tense to test production of past time reference (Abuom & Bastiaanse, 2013; Bastiaanse et al., 2011), while reference to the past can also be made through a periphrastic verb complex with a present tense auxiliary, such as in [*hij heeft<sub>present tense</sub> gegeten*]<sub>past time reference</sub>: ‘he has eaten’.

Chapter 3 described the use of the Dutch version of the TART to address this issue. The Dutch TART used periphrastic and simple verb forms for reference to the past, and compared production of these forms with production of the simple present. The results showed that both types of references to the past

are more impaired than reference to the non-past, both in agrammatic and fluent aphasia. Therefore, the data supported the claim that the PADILIH applies to time reference in general, not to tense per se. This corresponds to results from tenseless languages that use aspectual adverbs to express time reference, such as Standard Indonesian and Chinese, where discourse-linking poses problems for agrammatic aphasic speakers, too (Anjarningsih & Bastiaanse, 2011; Bastiaanse et al., 2011). However, in these languages, all aspectual adverbs are by default discourse-linked, and therefore the production of them is impaired overall. The aphasiological data of Chapter 5 also contribute to resolving this issue. For sentences with past time reference, aphasic participants showed a delay in processing the inflection with respect to healthy participants, while future time reference was processed at a similar pace in these two groups. This delay is expected based on the PADILIH and is irrespective of tense, since both verb forms contain an auxiliary in present tense.

The ERP-study with non-brain-damaged speakers in Chapter 4 also addressed this point. Similar to in the Dutch aphasiological study, Dutch periphrastic verb forms were used to untangle time reference and tense. In the experimental sentences, the time frame (past, non-past) was set by a temporal adverb, followed by a verb form. When the temporal restrictions were violated by an incorrect verb form, a P600 was elicited. The results 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 its tense. Therefore, the discourse-related processing differences between simple past and simple present verbs that supported the PADILIH (Dragoy et al., 2012) were due to time reference.

To conclude, the data suggest that past time reference difficulties are irrespective of tense. These data extend the idea based on Zagona (2003) that past tense is discourse-linked and support the PADILIH (Bastiaanse et al., 2011). The results entail that previously reported discourse-linking differences between verbs in past or non-past tense (e.g., in aphasia: Abuom & Bastiaanse, 2013; Bastiaanse et al., 2011; Martínez-Ferreiro & Bastiaanse, 2013; in healthy speakers: e.g., Baggio, 2008; Dragoy et al., 2012) are due to the time reference expressed by the verb form as a whole, and are thus a semantically rather than morphologically based.

### 6.1.4 Processing past time reference delayed in agrammatism

The fourth issue raised was the question of how people with agrammatic aphasia process time reference incrementally. The experiment in Chapter 5 investigated whether processing of future and past time reference inflection is different for non-brain-damaged and aphasic individuals. Furthermore, the study aimed to clarify how time reference processing breaks down in agrammatic aphasia. A visual-world experiment combining sentence-picture matching and eye tracking was performed in German. Non-brain-damaged and aphasic participants heard German sentences with periphrastic future or periphrastic past verb forms while they were presented with corresponding pictures on a computer screen. The results showed that there was a pre-existing preference to look at a past picture, which had to be overcome. This bias caused a below-ceiling performance on the future condition for the aphasic participants, and faster responses to the past than to the future condition in both participant groups. The interesting finding with respect to incremental time reference processing is that the eye movement patterns suggested that agrammatic aphasic individuals show a delay relative to NBDs in interpreting past time reference inflection. However, both groups interpreted future time reference in a similar way. These 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.

## 6.2 Directions for further research

The advantage of cross-linguistic research is that any shortcomings in one language might be overcome by including another language. The eye-tracking experiment was, for example, performed in German. The advantage of testing in this language was that a particular set of verbs could be used that could carry time reference inflection after the stem of the lexical verb instead of before, allowing incremental processing of verb inflection to be tested. The disadvantage was, however, that present time reference could not be tested in the same paradigm. Therefore, a follow-up in a different language should clarify how present time reference inflection is incrementally processed.

Techniques can also be complementary. The aphasiological experiments per-



formed for this PhD project suggest that brain damage has differential effects on how time reference difficulties surface: The agrammatic aphasic individuals described in Chapter 3 and in Dragoy and Bastiaanse (2013) were overall less stable than fluent aphasic speakers in assigning past time reference. This suggests that the brain areas typically implicated in agrammatic aphasic participants play a crucial role in discourse-linked time reference. Yet, an open question is which brain regions are engaged during the additional processing needed for discourse-linking in the healthy brain. EEG is not a suitable technique to address this question, given it has a low spatial resolution. However, functional magnetic resonance imaging (fMRI) can shed light on this.

Multiple fMRI studies have shown that the left inferior frontal gyrus (IFG) and supplementary motor area (SMA) are involved in processing of grammatical morphology (e.g., Sahin, Pinker, Cash, Schomer, & Halgren, 2009, Yu, Bi, Han, & Law, 2013), while in agrammatic aphasia the left IFG is often not functional (e.g., Damasio, 1991). Hence, the IFG is a likely candidate for the extra processing needed for past time reference. Another possibility is that the right hemisphere plays a role in the discourse-linking needed for reference to the past. Malfunctioning of the left IFG may lead to a disconnection with the contralateral area, which has been associated with discourse processing by Menenti et al. (2009). Furthermore, increased activation of the left IFG has been associated with greater processing complexity in selecting grammatical inflections (e.g., Sahin et al., 2009). The left IFG is, thus, a candidate for the additional activation needed for reference to the past. In order to find out whether and where additional brain activation is found for past versus non-past time reference production, an fMRI study has been performed, and the data will be further analysed (for preliminary data see: Bos, Bastiaanse, Ries, & Wartenburger, 2014).

The status of future time reference deserves more attention. The ERP-data from Chapter 4 support a two-way tense structure, distinguishing past and non-past tense (Aronson, 1977; Partee, 1973; Zagana, 2003, 2013). However, the TART (Bastiaanse et al., 2008) data described in Chapter 5 point to a similar impairment of past and future time reference comprehension in German. The periphrastic verb form used for future time reference is, nonetheless, not the only form used in that language. In many languages, the simple present tense is used for future time reference. In Spanish and Catalan, there was also a performance drop in the comprehension of future time reference on the

TART (Martínez-Ferreiro & Bastiaanse, 2013), however, the past was still more impaired. In other languages, where present tense cannot be used for future time reference, the TART showed that present and future time reference were equally well preserved (e.g., Abuom & Bastiaanse, 2013; Bastiaanse et al., 2011). This suggests that the time reference system of a particular language plays a role in the difficulties that aphasic individuals experience. Indeed, in languages such as Standard Indonesian and Chinese, time reference production is overall impaired (Anjarningsih & Bastiaanse, 2011; Bastiaanse et al., 2011) which Bastiaanse (2013) claims to be due to the optionality of aspectual adverbs that are therefore, by default, discourse-linked. Maybe future time reference is difficult due to the fact that — even though it does not require discourse-linking — it is different from present time reference because it is not locally bound (based on Zagona, 2013, and the PADILIH, Bastiaanse et al., 2011). Further research should clarify what other properties of the time reference system of a language contribute to time reference difficulties, and to future time reference in particular.

More aphasiological research is needed. The study in Chapter 2 confirmed that comprehension of discourse-linked structures is problematic in aphasia. The study in Chapter 3 showed that past time reference and not tense is the decisive factor for inflection problems of agrammatic speakers. The study in Chapter 5 revealed that past time reference inflection is processed more slowly by agrammatic aphasic individuals than by non-brain-damaged individuals. This knowledge can be taken into account in the analysis of aphasia assessment, and in the development of new therapy materials.

Verbs are an important focus of rehabilitation of aphasia, for example because an improvement in the number of finite verbs in agrammatic spontaneous speech improves their daily communication capacities (Links, Hurkmans, & Bastiaanse, 2010). The simple past form is difficult for Dutch fluent aphasic speakers, which makes them resort to an easier construction that refers to the past. For these fluent aphasic speakers, the periphrastic past is such a construction: It carries tense and agreement inflection on the auxiliary and not on the lexical verb. It is possible to train the production of past time reference forms (Harris, Olson, & Humphreys, 2012; Wieczorek et al., 2011). However, in such training one must keep in mind the possible inverse relationship between lexical diversity and time reference inflection. A focus on the use of appropriate lexical verbs can result in more comprehensible and informative speech than a

focus on verb inflection (Bastiaanse, 1995). Training of correct and complete sentences is therefore less important than the training of the diversity of lexical verbs.

Not all aphasia types described in Section 1.1.1 have been studied in relation to time reference. Also within the two main types of aphasia, agrammatic and fluent aphasia, some open questions remain. For example, time reference expression in spontaneous speech of Dutch aphasic speakers has not been studied yet. In formal testing, the agrammatic aphasic speakers of Dutch tended to avoid discourse-linked processing by not referring to the past (Chapter 3). The fluent aphasic speakers, however, avoided the simple past form and resorted to an easier construction that refers to the past. The periphrastic past is such a construction: it carries tense and agreement inflection on the auxiliary and not on the lexical verb. The relationship between lexical access, verb finiteness, and time reference inflection in Dutch needs further research, for example by spontaneous speech analysis.