The brain, verbs, and the past

Neurolinguistic studies on time reference

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Amsterdam, July 22, 2014

Contents

List of Figures

List of Tables

CHAPTER 1

General introduction

Verbs play a key role in a sentence and thereby in daily communication. They express the event and carry information on the relationship between the constituents in a sentence. Part of this information concerns the temporal characteristics of the situation being described: both about the point in time in which an event takes place and about the order of events. In aphasia — an acquired language disorder due to focal brain damage — verbs are a vulnerable category (Bastiaanse & Edwards, 2004). This dissertation zooms in on one of the sources of the problems with verbs, namely their time reference characteristics. Furthermore, parallels with other referential processes will be sought in order to investigate the underlying mechanisms of time reference processing. Throughout the following chapters, the scope is broadened to include aphasia subtypes and unimpaired language processing.

1.1 The study of aphasia

In the Netherlands, around 30.000 people suffer from aphasia. In around 85% of the cases, aphasia is the result of a stroke. Other causes can be traumatic brain injury, a tumor, or an infection. For 95-97% of the right-handed and 70% of the left-handed people, language is represented in the left hemisphere (Bastiaanse, 2010). Aphasia is therefore most often the result of a brain lesion involving the left hemisphere. The word aphasia, first used by Trousseau (1864), has its roots in the Greek 'αφατος' (aphatos), which means 'no speech'. This translation can be misleading: Aphasia is primarily a language disorder, not a speech disorder. Production and comprehension are impaired to a greater or lesser extent. Studying the underlying deficits in aphasia is an important part of forming a better understanding of the surfacing problems that individuals with aphasia experience, and is an important part of improving the treatment of aphasic symptoms. Furthermore, the study of aphasia can inform linguistic theory.

Many aphasiologists set the starting point of modern aphasia research in the second half of the 19th century. In 1861, French surgeon, anatomist and anthropologist Paul Broca (1824-1880) discovered the 'speech center'. Broca described his first patient 'Mr. Tan' (Mr. Leborgne) as being unable to coordinate the movements that are associated with articulated speech. The only syllable he could pronounce was 'Tan'. Broca related this inability to a lesion he found in the post-mortem brain of Mr. Leborgne. Broca's contemporary Carl Wernicke (1848-1904) was a German assistant-neurologist who discovered that a lesion in the posterior part of the superior temporal gyrus resulted in 'sensory' aphasia. Both the region and the aphasia type associated with a lesion in this area now carry his name. The publications of Broca and Wernicke form milestones in aphasiology, although earlier reports of cases of acquired language disorders dating from 1700 BC onwards can be considered the prerequisites for later advances (Prins & Bastiaanse, 2006). In the following paragraphs, the two main systems of syndrome classifications will be discussed, namely, the classification by the Boston school (consisting of, amongst others, Geschwind, Benson, Alexander, Goodglass, and Kaplan), and the syndrome classification by the Russian neuropsychologist Luria. The individuals with aphasia that took part in the comprehension and production experiments of the current dissertation were classified by either one of those two systems.

1.1.1 Aphasia syndromes

The 'Boston Diagnostic Aphasia Examination' (BDAE; Goodglass & Kaplan, 1972), a standardized aphasia test, was developed from 1960 onwards by Harold Goodglass (1920-2002) and his colleagues. They set out a classification system with different syndromes. In the Boston framework, syndromes due to pre-Rolandic lesions have a non-fluent speech output and syndromes due to temporal and temporoparietal lesions have fluent speech output. Non-fluent aphasias are Broca's aphasia, transcortical motor aphasia, and global aphasia.

Broca's aphasia is the main type of non-fluent aphasia and characterized by telegraphic speech. A symptom of Broca's aphasia is agrammatism: Grammatical morphemes and function words such as determiners and pronouns are often omitted or substituted in production (Berndt & Caramazza, 1980). Comprehension of everyday language is relatively spared although grammatically more complex sentences are more poorly understood, as will be described in the next section. This syndrome is named after Paul Broca, even though it does not apply to his famous case study. Individuals with this type of aphasia usually have a lesion including connections to Brodmann's areas 44 and 45 in the left hemisphere, commonly referred to as 'Broca's area'. Areas encompassing Broca's region are typically involved in combinatory operations on the syntactic, semantic and phonological level (Hagoort, 2006). Regularly, Broca's aphasia is accompanied by apraxia of speech.

Transcortical motor aphasia is another non-fluent aphasia form. It is characterized by relatively intact comprehension while spontaneous utterances are limited. Repetition is, however, intact. In the Boston system, also the severe aphasia syndrome *global aphasia* is distinguished, with very limited to non-existent language production, often combined with severe apraxia of speech and impaired comprehension.

The main fluent aphasic syndrome is *Wernicke's aphasia*. Individuals suffering from this syndrome produce phonemic and/or verbal paraphasias and neologisms in their speech. In severe cases this leads to so-called 'jargon', which is incomprehensible language output. Repetition is impaired. Furthermore, word comprehension is compromised, which leads to a deficit in sentence comprehension. In the syndrome *anomic aphasia*, the comprehension of words and sentences that are not too grammatically complex are relatively spared. People suffering anomic aphasia experience most problems with word finding, which is where the name of the syndrome stems from. Production characteristics are circumlocutions and empty speech (Bastiaanse, 2010). The syndrome *conduction aphasia* is characterized by fluent speech with many phonemic paraphasias, especially during repetition. Comprehension is relatively good, which enables self-monitoring. This combination leads to 'conduites d'approches'; repetitive attempts to correct ones own verbal output. The symptoms of *transcortical sensory aphasia* are more or less similar to those of Wernicke's aphasia, but repetition is spared.

The neuropsychologist Alexander Romanovich Luria (1902-1977) investigated traumatic brain injuries of hundreds of Second World War soldiers and identified six types of aphasia (1966). *Efferent motor aphasia* roughly equals Broca's aphasia. *Dynamic aphasia* is a disruption in converting internal speech into spoken utterances and shares some characteristics with transcortical motor aphasia. *Afferent motor aphasia* is roughly equivalent to apraxia of speech, and therefore an articulatory disorder rather than a language disorder. *Sensory aphasia* is comparable to Wernicke's aphasia. *Semantic-mnestic aphasia* is translatable into anomic aphasia. The sixth syndrome Luria described is *acoustic-mnestic aphasia* and is characterized by anomia and problems with verbal memory. It can be considered a special subtype of conduction aphasia, where the main characteristic is a problem in retention of acoustic traces in memory, leading to comprehension problems. Table 1.1 shows the main characteristics per syndrome of the Boston classification, with (where applicable) the rough equivalents in Luria's system.

Table 1.1: Overview of the classical aphasia types in the Boston group system (based on Table 2.1 in Bastiaanse, 2010), and some rough equivalents in Luria's system. Not included in the table is Luria's afferent motor aphasia (roughly equivalent to apraxia of speech).

Aphasia classification		Fluency	Compr.	Repet.	Characteristic
Boston	*Luria*				
Broca's	Efferent motor	-	+	-	Telegraphic speech
Transc. motor	Dynamic	-	+	+	Relatively spared repetition
Global		-	-	-	All modalities disturbed
Wernicke's	Sensory	+	-	-	Paraphasias
	Acoustic-mnestic	+	-	-	Impaired verbal memory, anomia
Anomic	Semantic-mnestic	+	+	+	Word finding difficulties
Conduction		+	+	-	Phonemic paraphasias
Transc. sens.		+	-	+	Relatively spared repetition

Compr. = Comprehension; Repet. = Repetition; Transc. sens. = Transcortical sensory; Transc. motor = Transcortical motor; '+' = relatively spared, '-' = relatively impaired.

In his aphasia classification, Goodglass acknowledged the limitation that less than half of the individuals with aphasia have a language profile that fits one of these syndromes (Goodglass, 1981). Still, such classifications are useful, for example, when scientific group studies are performed. Generalizations can be made over individuals with a certain aphasia type, even though exceptions to the rule are possible. In the current dissertation, the somewhat broader distinction agrammatic versus fluent aphasia is used, as discussed in the next section.

1.1.2 Agrammatic and fluent aphasia

In the current dissertation, two major aphasia types are distinguished based on speech output, namely non-fluent agrammatic aphasia and fluent aphasia. Since the 19^{th} century, these two broad types have been distinguished under different names (Ardila, 2010). The terms non-fluent aphasia, Broca's aphasia, and agrammatic aphasia are often used intermingled. However, they are not equivalent. Broca's aphasia is a syndrome classification, of which the speech is characterized by non-fluency and agrammatism. The latter two are not equivalent either: Non-fluent speech can be grammatically correct. Studies of fluent aphasia often include participants with Wernicke's aphasia, although participants with other types of fluent aphasia (such as the other types described in Section 1.1.1) may also be included in them. In the remainder of this section, the characteristics of verb processing in agrammatic and fluent aphasia will be discussed.

In agrammatism, the likelihood of a grammatical morpheme being omitted is related to its function. The inflection for subject-verb agreement is often preserved (but see Burchert, Swoboda-Moll, & De Bleser, 2005; Friedmann & Grodzinsky, 1997; Wenzlaff & Clahsen, 2004), while tense inflection is markedly impaired (e.g., in English: Dickey, Milman, & Thompson, 2005; in Dutch: Kok, van Doorn, & Kolk, 2007; in German: Burchert et al., 2005; in Hebrew: Friedmann & Grodzinsky, 1997; in Greek: Stavrakaki & Kouvava, 2003; and in Ibero-Romance languages: Gavarró & Martínez Ferreiro, 2007). Furthermore, the base order of a sentence is easier than a derived order (Bastiaanse & van Zonneveld, 2005). The more arguments a verb has and the more syntactic operations have to be applied to a sentence structure, the more problematic the production of the sentence is for this group of patients (Dragoy & Bastiaanse, 2010, Thompson, 2003). Agrammatic aphasia is a central deficit: it affects production as well as comprehension in both spoken and written language. However, the problems in comprehension in daily life are relatively spared compared to production: The comprehension deficit reveals itself when non-canonical and and/or reversible sentence structures are used (e.g., Bastiaanse & Edwards, 2004; Caramazza & Zurif, 1976; Faroqi-Shah & Dickey, 2009).

Fluent aphasia is characterized by word-finding difficulties (anomia). Fluent aphasic speakers have problems to access the lexical word forms. In addition, Bastiaanse (2011) and Bastiaanse and Edwards (2004) showed that there is a relation between word-finding difficulties and morphosyntax, and that also in fluent aphasia, finite verb forms that are inflected for tense and aspect are more difficult to produce than non-finite verbs. Bastiaanse (2011) shows that the range of lexical verbs that fluent aphasic speakers use is smaller in contexts where more computation is needed to integrate the intra-sentential information (such as agreement) and extra-sentential information (such as tense).

1.2 Theoretical background

In this dissertation, theories from theoretical linguistics and neurolinguistics are combined to explain processing difficulties with verb inflection that refers to the past in aphasia and in the healthy brain. In the following sections, the theoretical background is set out.

1.2.1 Discourse-linking and tense

Producing and comprehending language requires an interaction of linguistic domains such as morphology, syntax and discourse. The contribution of these domains differs per linguistic element: a personal pronoun, for example, depends more heavily on discourse than a reflexive pronoun, as will be explained in this paragraph.

In theoretical linguistics, a distinction is made between discourse structure and narrow syntax. Processing at the level of narrow syntax activates the lexical and syntactic features of linguistic elements — this is the stage where lexical elements receive their meaning and where computations are made over these elements. When elements are *discourse-linked* (or: D-linked; Pesetsky, 1987), their representation goes beyond the boundaries of the sentence, because they have a specific referent, or set of referents, that need to be identified in discourse and linked to. This connection between their narrow syntactic and discourse representation is necessary to ensure that their grammatical function and eventual interpretation correspond. Importantly, processing such discourse-linked elements requires additional operations.

Discourse-linking plays a role in various linguistic operations such as *wh*-questions, pronoun resolution and tense. Compared to a *who*-question, a *which*question requires integration of discourse presuppositions and syntax. For example, in the sentence *Which woman is talking to the man?*, there is a set of women presupposed, for which access to discourse structure is needed. However, in the sentence *Who is talking to the man?*, this is not the case and processing can take place in narrow syntax alone.[1] Likewise, a personal pronoun refers to a specific discourse element, for example in *The* man_i *shaves [*him_j*]*, where *him* links to someone identified in discourse structure. Making such a discourse link is not needed for *The* man_i *shaves [*$himself_i$*]*, where the referent of the reflexive pronoun *himself* is in the same clause.

Tense (in combination with aspect) can be used to refer to a certain time frame. Hans Reichenbach (1891-1953) was a pioneer in the field of tense theory. In his 1947 book, he set up a framework in which he identifies a three-way structure of tense. He called the time point at which an utterance is produced, the *point of speech* (S). He argued that a division in before, simultaneous and after the point of speech would not be sufficient to describe all tenses, but that there are two events besides the point of speech that have to be identified: the *point of the event* (E) and the *point of reference* (R), which both are positioned with respect to the point of speech. The positions of the point of speech and reference determine whether the verb refers to past, present or future. In the present perfect for example, E precedes the simultaneous S and R. In the simple past, R and E overlap and precedes S.

Reichenbach's ternary tense system forms the basis of a line of research on the anaphoric nature of tense (e.g., Enç, 1987; Partee, 1973, Zagona, 2003, 2013). According to Enç (1987), tense is binary and consists of features for the *event time* (in the tense node) and for the *anchor time* (in the complementiser node). The anchor time is comparable to the point of speech in Reichenbach's framework (1947): it is the time when the sentence is thought, heard, or said.

[1]Salis and Edwards (2008) brought forward an alternative view on the difference between *who*-and *which*-questions. They argue that *which* creates a subset within the set the subsequent noun refers to, being computationally more demanding than when no set partition is required, with *who*. Donkers, Hoeks and Stowe (2013) argue for a similar account to explain their reaction time data collected from a group of healthy participants. Also Thompson et al. (1999) seek the origin of the marked deficit of *which*-questions in its higher semantic complexity.

For present tense, the event time and anchor time are co-indexed (i.e., they overlap), while for past tense the reference of the event time and anchor time is not the same. Partee (1973) singled out the referential characteristics of tense and compared them to pronominal reference. She substantiated that both tense and pronouns can be locally bound (i.e. within the sentence) or linked to an antecedent in the discourse representation, such as a temporal adverb or another event.

Zagona (2003), however, argues that present tense is less dependent on discourse than past tense. She argues that while present tense is bound to the temporal anchor, this is not the case for past tense: it is in sequential relation with it. Only past tense is, thus, discourse-linked in her framework. She further proposes that future should be seen as a form derived from the present tense via modal and aspectual features[2] (Zagona, 2013) and is neither discourse-linked nor bound.[3] This means that, in line with Aronson (1977) and Partee (1973), she distinguishes between past and non-past tense.

In the current dissertation, a distinction between past and non-past *time reference* is made. Tense is something different than time reference. In Germanic languages such as English, Dutch, and German, reference to the *past* can be made with a verb form consisting of an auxiliary in *present* tense plus a participle, for example:

English:	he	[$\text{has}_{\text{present tense}}$	written	$]_{\text{reference to the past}}$
Dutch:	hij	[$\text{heeft}_{\text{present tense}}$	geschreven	$]_{\text{reference to the past}}$
German:	er	[$\text{hat}_{\text{present tense}}$	geschrieben	$]_{\text{reference to the past}}$

Tense is a morphological inflection on a verb, that expresses the temporal relation between the time interval of the event and the time of evaluation set by the context, for example 'simultaneity' or 'precedence'. *Time reference*, however, can be conveyed through a combination of tense, aspect, and context. *Aspect* conveys information about the temporal boundaries of an event such as the beginning and end point. Time reference is therefore a semantic characteristic of a verb form as a whole.

[2]Reichenbach's (1947) explanation of the origin of future tense inflection aligns with the view that future tense is derived from present tense by modal features. He described the origin of the English future formed by 'shall' and the infinitive. In the middle ages, 'shall' was used to express an obligation. As a result of this obligation, the action denoted by the verb will be done at a later time. He gives a similar account for French, where the future tense evolved out the infinitive and conjugations of *avoir*: 'to have to', for example *je donnerai*: 'I will give', evolved out of *je donner ai*: 'I have to give'.

[3]K. Zagona, personal communication with R. Bastiaanse, September 16, 2010.

1.2.2 The PAst DIscourse LInking Hypothesis (PADILIH)

Problems with grammatical encoding and decoding are prominent in agrammatic aphasia, but not all linguistic operations are impaired to the same degree. Finite verb forms (corresponding in number and person with the grammatical subject) are for example difficult to produce (Burchert et al., 2005; Clahsen & Ali, 2009; Friedmann & Grodzinsky, 1997; Gavarró & Martínez-Ferreiro, 2007; Kok, Kolk, & Haverkort, 2006; Kok et al., 2007; Wenzlaff & Clahsen, 2004, 2005; Wieczorek, Huber, & Darkow, 2011). However, tense and aspect inflections are generally found to be more impaired than agreement inflection (Clahsen & Ali, 2009; Friedmann & Grodzinsky, 1997; Gavarró & Martínez-Ferreiro, 2007; Kok et al., 2006; Kok et al., 2007; Wenzlaff & Clahsen, 2004, 2005; Wieczorek et al., 2011), although some studies report equal or worse impairment of agreement inflection (e.g., Burchert et al., 2005; Lee, Milman, & Thompson, 2008).

Avrutin (2000, 2006) claims that linguistic structures that are processed by discourse syntax (i.e., discourse-linked), are more impaired in Broca's aphasia than structures that are processed by narrow syntax alone. He explains that discourse-linking requires proportionally more brain activation, which the aphasic individuals lack. He supports this claim with data from *wh*-word processing (Hickok & Avrutin, 1995) and pronominal reference (Ruigendijk et al., 2003; see also Edwards & Varlokosta, 2007; Grodzinsky et al., 1993; Ruigendijk, Vasić, & Avrutin, 2006). According to Avrutin, tense is more difficult than agreement, because tense requires access to discourse structure.

Bastiaanse and colleagues (Bastiaanse, 2008, 2013; Bastiaanse et al., 2011) further elaborated on Avrutin's claim that tense needs discourse access, after they found that verb forms that refer to the past are more impaired than verb forms with non-past time reference. In order to explain their findings, they combined the idea of discourse-involvement for past tense set out by Zagona (2003, 2013), and impaired discourse-linking in aphasia, claimed by Avrutin (2000, 2006). However, they extend the theory further, claiming that discourse-linking is required for all verb forms that refer to the past, irrespective of the linguistic means employed. This theory forms the basis of the PAst DIscourse LInking Hypothesis (PADILIH; Bastiaanse et al., 2011), which holds that discourse-linking is needed for verb forms that refer to the past. The PADILIH can thus account for a greater difficulty in reference to the past as compared to present or future. For a schematic illustration of the PADILIH, see Figure 1.1.

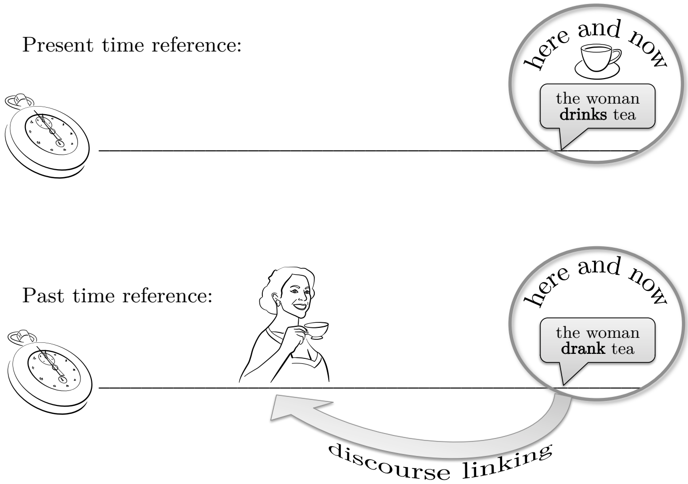

Figure 1.1: Schematic illustration of the PADILIH. The upper time line illustrates present time reference in the sentence *the woman drinks tea*. For present time reference, no discourse-linking is needed: The sentence can be interpreted in the here and now of the moment of speaking. The lower time line illustrates past time reference in the sentence *the woman drank tea*. For past time reference, a link needs to be made to the event in discourse. For this, additional processing in information structure is required (Bastiaanse et al., 2011). This access is impaired in agrammatic aphasia (Avrutin, 2000, 2006). Line drawings by Michel Holper, www.parap.lu.

The PADILIH is backed up by cross-linguistic data collected with different research paradigms in different populations. Bastiaanse, Jonkers, and Thompson (2008) developed the Test for Assessing Reference of Time (TART; see Chapter 2, 3 and 5 for more background on this test), which has been adapted to a range of languages. The results of the TART show that for agrammatic aphasic speakers of for example English, Turkish, Spanish, Catalan, and Swahili-English (bilingual), verbs referring to the present and future are easier to produce and comprehend than verbs referring to the past (Abuom & Bastiaanse, 2013; Bastiaanse et al., 2011; Martínez-Ferreiro & Bastiaanse, 2013) However, there was an overall impairment of time reference production in Chinese (Bastiaanse et al., 2011). In Chinese, time reference of verbs is expressed with aspectual adverbs. These aspectual adverbs are optional, and only used if the time reference is not yet specified in discourse. Therefore, Bastiaanse (2013) argues that expressing time reference with a verb in Chinese is discourse-linked by default. This claim is borne out in another language that uses aspectual adverbs, namely Standard Indonesian (Anjarningsih & Bastiaanse, 2011). More production studies (with different methodology) supporting the PADILIH are discussed in Chapter 3, and more comprehension studies in Chapter 2 and 5.

Few studies addressed time reference in fluent aphasia. In everyday language, verb inflection is not problematic for fluent aphasic speakers. However, in experimental settings, some studies suggest that in fluent aphasia, producing verbs with past time reference is also more difficult than non-past time reference (Dragoy & Bastiaanse, 2013; Jonkers & de Bruin, 2009; Kljajevic & Bastiaanse, 2011; Wieczorek et al., 2011), although fluent aphasic speakers refer to the intended time frame more consistently than agrammatic speakers do (Dragoy & Bastiaanse, 2013). To sum up, the complexity of discourse-linked time reference seems to play a role across aphasia types, but the problems may surface differently.

The PADILIH has been claimed to apply to language use in general, not only to aphasia. Support comes from grammaticality judgment studies with non-brain-damaged participants. These studies used sentences with temporal adverbs/adjuncts followed by a verb in the past or present tense. Violations of a temporal context by verbs in present tense evoke longer reaction times than time reference violations by verbs in present tense (Faroqi-Shah & Dickey, 2009; Dragoy, Stowe, Bos, & Bastiaanse, 2012). In Baggio (2008) and Dragoy et al., neurophysiological brain responses to the time reference violations were measured with electroencephalography (see Section 1.3.1 for background on this technique). Dragoy and colleagues related the neurophysiological brain responses to studies of discourse-linking in the pronominal domain. Their results are in line with the claim that past time reference processing requires discourse-linking, while present time reference can be processed in narrow syntax alone.

1.3 Methodological background

In the current dissertation, different offline and online, behavioral and physiological methodologies will be used to address issues concerning time reference inflection. Offline tasks require overt, explicit responses from the participant, such as in sentence-picture matching. Therefore, they depend on metalinguistic knowledge. Online tasks measure performance *during* (linguistic) processing by the participant. Reaction times are online behavioral responses.

Online physiological measures are, for example, event-related brain potentials (ERPs) and eye-tracking. These will be introduced below, followed by a statistical technique used to analyze accuracy and reaction time data in the aphasia studies of the current dissertation. The relevant characteristics of the languages under study (Dutch, German and Russian) will be specified in the introduction of each concerning chapter.

The use of converging methods can enlighten different aspects of the research questions. For example, eye-tracking may reveal that offline chance performance is not due to guessing by the participants (e.g., Dickey, Choy, & Thompson, 2007; Hanne, Sekerina, Vasishth, Burchert, & De Bleser, 2011). Eyetracking can reveal incremental sentence processing, but practical matters (e.g., location, available time and money) might render an offline, behavioral task more appropriate. If accuracy data call for further investigation, more sophisticated techniques can be applied. Therefore, the studies in this dissertation have been performed using different techniques.

1.3.1 Event-related potentials (ERPs)

When the brain processes information, neurons communicate with each other, which generates electrical activity. The first person that reported to have measured electrical activity produced by the human brain was Hans Berger, in 1929. Berger placed an electrode over the scalp, amplified the signal, and plotted the changes in voltage over time in an *electroencephalogram* (EEG). The technique has been further developed ever since and is now a non-invasive method of studying neurophysiological activity of the brain. A raw EEG is difficult to read, because the measurements of one electrode reflect combined ongoing brain activity from hundreds of sources, that may not even all stem from the brain itself — a signal oscillating at 50 or 60 Hertz may for example stem from a nearby socket in the wall.

In 1935 and 1936, Pauline and Hallowell Davis started developing a method to extract the activation of particular processes (events) by averaging across multiple trials, resulting in *event-related potentials* (ERPs; see Luck, 2005, for ample background on this technique). By averaging, it is possible to cancel out random background noise and unrelated brain processes, provided they are not time-locked in a similar manner as the brain responses to the event. The electricity measured over the scalp is the summation of activity from neurons in various locations in the brain that fire in the same direction. The spatial resolution is therefore limited, but the temporal resolution is high. This makes ERP analysis a suitable measure to study online brain processing. ERPs can be related to different levels of linguistic processing, including grammar.

1.3.2 Eye-tracking in the visual-world paradigm

There is a systematic relationship between eye movements and speech processing, as Cooper (1974) discovered. Gazes are drawn to objects associated with what is being heard in a closely time-locked manner (within 200 ms after word onset). This finding forms the basis of what Allopenna, Magnuson, and Tanenhaus (1998) called the visual world paradigm (for a review, see Huettig, Rommers, & Meyer, 2011). In visual world studies, participants listen to sentences while inspecting a scene, for example line drawings or clip art pictures on a computer screen. Typically, the scene includes objects that are mentioned in the sentence, and some distractor objects. Eye-tracking measures the direction of visual attention, which depends on integrated visual and auditory input. The results can be used to study the interpretation of sentences (the activation of conceptual and lexical knowledge) online.

1.3.3 Linear mixed-effects regression modeling

In most aphasiological group studies, there is substantial within-group variation, because lesions differ from person to person and can affect language to various degrees. Furthermore, group sizes are often relatively small. When analyzing aphasiological data, it is, therefore, crucial to handle outliers appropriately in order to avoid incorrect interpretation of the data. Linear mixed-effects regression modeling (LME; for an introduction see Baayen, 2008) is a useful technique for that matter, because it is robust to outliers, in contrary to for example a repeated measure analysis of variance (ANOVA). Another advantage of LMEs over ANOVAs is that in LMEs, by-item and by-participant variation can be taken into account simultaneously. Traditionally, two separate analyses were used, min-F' estimates (Clark, 1973; Raaijmakers, Schrijnemakers, & Gremmen, 1999), which are less powerful. Individual variation in the participants' responses to condition can be accounted for by the inclusion of random slopes in LMEs. This allows generalization over a group of participants with individual variation and is particularly relevant for the analysis of aphasia data.

1.4 Issues addressed in the current dissertation

In the previous sections aphasia was explained. A range of studies provided evidence for the claim that in agrammatic aphasia, reference to the past is more difficult than reference to the present or future in comprehension and in production (e.g., Abuom & Bastiaanse, 2013; Bastiaanse et al., 2011; Martínez-Ferreiro & Bastiaanse, 2013). Also in fluent aphasia, a verb with past reference seems to be more difficult to process than a verb with present reference (Dragoy & Bastiaanse, 2013; Jonkers & de Bruin, 2009; Kljajevic & Bastiaanse, 2011; Wieczorek et al., 2011). These differences were captured in the PADILIH (Bastiaanse et al., 2011), which holds that discourse-linking is needed for past time reference, which makes past time reference more difficult to process for individuals with aphasia than non-past time reference.

The PADILIH is based on Zagona's idea (2003, 2013) that past tense needs more discourse involvement than non-past tense, and on Avrutin's idea that people with agrammatic aphasia have limited access to discourse syntax. Bastiaanse et al. (2013) extended their ideas and claimed that it is past time reference that is discourse-linked, irrespective of the tense employed. Discourse-linking difficulties were also observed in the pronominal domain (Edwards & Varlokosta, 2007; Grodzinsky et al., 1993; Ruigendijk et al., 2006) and in comprehending *wh*-phrases (Avrutin, 2000). The brains of healthy speakers reflect discourse-related processing differences for violations by past and present time reference (Dragoy et al., 2012). The current dissertation describes neurolinguistic investigations of time reference that address unresolved issues of the PADILIH. The following issues will be addressed with different methodologies throughout the chapters:

1. The first issue relates to the claim that past time reference is problematic in aphasia because it is discourse-linked. Support for this claim can be found by showing that discourse-linking is impaired in aphasia across linguistic structures within the same participant group.

2. The second issue is the question whether the PADILIH can be generalized across aphasia type and to language processing in general. The hypothesis was posed to describe data from agrammatic aphasia. There are, however, some studies that show that discourse-linking (including past time reference) increases processing load and errors in fluent aphasia. Discourse-related processing differences between past and non-past

time reference have been observed in ERP responses of the healthy brain, too (Dragoy et al., 2012). The generalizability of the PADILIH has not received enough attention to date.

3. The third issue addressed in this dissertation is the question whether the PADILIH applies to past time reference, irrespective of tense. According to Zagona (2003) past tense is discourse-linked, however, Bastiaanse et al. (2011), extend her claim to past time reference in general. Previous studies with the TART (Bastiaanse et al., 2008) used the past tense to test production of past time reference, while reference to the past can also be made through a verb complex with a present tense auxiliary. As a result, in previous studies with aphasic speakers, time reference could not be untangled from tense. In the current dissertation, therefore, whether comprehension and production difficulties in aphasia are irrespective of tense is investigated. Furthermore, whether discourse-related processing differences in non-brain-damaged individuals that were found for past and non-past *tense* violations (Dragoy et al., 2012), are also found for past-and non-past *time reference* violations is investigated.

4. The fourth issue is incremental time reference processing by people with agrammatic aphasia. So far, no online physiological study of time reference processing in aphasia has been published. Even when offline interpretation of time reference is correct, still, incremental online processing may reflect deviant processing when compared to non-brain-damaged speakers. Furthermore, when agrammatic aphasic individuals comprehend time reference incorrectly, it is not clear at what stage of sentence they lose track of time reference.

1.5 Outline of the dissertation

The following chapters of this dissertation each contribute to one or more of the issues raised at the end of the previous section. This section provides an overview:

Chapter 2 is concerned with the first issue of whether past time reference is discourse-linked, and with the issue whether the PADILIH extends to comprehension in fluent aphasia. The Chapter contains data of three sentence-picture-matching tasks administered to agrammatic and fluent aphasic Russian speakers. The described study tested, for the first time, three types of discourse-linking structures within the same population, in order to find out whether discourse-linking is the common denominator of the deficits in time reference, *wh*-questions, and object pronouns. Secondly, the study aims to compare the comprehension of discourse-linked elements in people with agrammatic and fluent aphasia.

Chapter 3 addresses the second issue, whether the PADILIH extends to fluent aphasia, and the third issue, whether the PADILIH applies to past time reference rather than past tense. This chapter describes data from a sentence completion task administered to agrammatic and fluent speakers of Dutch. The sentences had to be completed with simple past tense, the periphrastic past (containing an auxiliary in present tense) and the simple present tense. The PADILIH predicts that both conditions testing production of reference to the past are more impaired than the condition testing production of reference to the non-past. Past time reference may pose problems for both aphasic participant groups, but an error analysis can reveal whether the problem surfaces differently.

Chapter 4 addresses the third issue in non-brain-damaged speakers: It aims to untangle time reference from tense in the discourse-related ERP effects described by Baggio (2008) and Dragoy et al. (2012). The study employed sentence structures similar to those used by Dragoy and colleagues, however, it included both periphrastic verb forms (consisting of an auxiliary plus a lexical verb) and simple verb forms. The materials allow us to draw conclusions on whether the effects described by Dragoy et al. and Baggio stem from time reference or tense characteristics of the verb forms.

Chapter 5 addresses the third issue (untangling time reference from tense) and fourth issue (incremental time reference processing). The study described in this chapter uses combined eye-tracking and sentence-picture-matching with sentences containing periphrastic verbs that refer either to the past or to the future. Both verb forms contain an auxiliary in present tense, so that differences between conditions cannot be ascribed to tense per se. The study aims to clarify whether processing of future and past time reference inflection differs between non-brain-damaged individuals and individuals with agrammatic aphasia. Furthermore, it sheds light on the underlying mechanisms of time reference comprehension failure by individuals with agrammatic aphasia.

Chapter 6 contains the general discussion of all findings of the dissertation. It addresses the four main issues raised in the previous section. The implications and proposed directions for further studies are then discussed.

CHAPTER 2

Understanding discourse-linked elements in aphasia: A threefold study in Russian[1]

Abstract — *Background*: Agrammatic speakers have problems with grammatical encoding and decoding. However, not all syntactic processes are equally problematic: present time reference, *who*-questions, and reflexives can be processed by narrow syntax alone and are relatively spared compared to past time reference, *which*-questions, and personal pronouns, respectively. The latter need additional access to discourse and information structures to link to their referent outside the clause (Avrutin, 2006). Linguistic processing that requires discourse-linking is difficult for agrammatic individuals: verb morphology with reference to the past is more difficult than with reference to the present (Bastiaanse et al., 2011). The same holds for *which*-questions compared to *who*-questions and for pronouns compared to reflexives (Avrutin, 2006). These results have been reported independently for different populations in different languages. The current study, for the first time, tested all conditions within the same population.

[1]This chapter was adapted from: Bos, L.S., Dragoy, O., Avrutin, S., Iskra, E., & Bastiaanse, R. (2014). Understanding discourse-linked elements in aphasia: A threefold study in Russian. *Neuropsychologia, 57*, 20-28.

Aims: We had two aims with the current study. First, we wanted to investigate whether discourse-linking is the common denominator of the deficits in time reference, *wh*-questions, and object pronouns. Second, we aimed to compare the comprehension of discourse-linked elements in people with agrammatic and fluent aphasia. *Methods and procedures*: Three sentence-picture-matching tasks were administered to 10 agrammatic, 10 fluent aphasic, and 10 non-brain-damaged Russian speakers (NBDs): (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.

Outcomes and results: NBDs scored at ceiling and significantly higher than the aphasic participants. We found an overall effect of discourse-linking 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.

Conclusions: The results are in line with the prediction that problems that individuals with agrammatic and fluent 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 effect is not specific to agrammatism, although it may result from different underlying disorders in agrammatic and fluent aphasia.

2.1 Introduction

2.1.1 Discourse-linking theory and aphasia

Agrammatic aphasic individuals encounter problems with grammatical decoding. However, not all syntactic processing is equally problematic, which becomes apparent in studies that involve the relationship between different linguistic levels, specifically and most notably between narrow syntax and discourse structure. Processing at the level of narrow syntax activates the lexical and syntactic features of linguistic elements and involves computations over these elements. Discourse-linked elements have representation beyond the sentence boundaries, because they have a specific referent, or set of referents, that need to be identified. Pesetsky (1987) argues that for D(iscourse)-linked elements a specific connection between their syntactic and discourse representation is required to ensure a correspondence between their grammatical function and eventual interpretation. In other words, processing such elements requires additional operations. Taking as an example a difference between reflexive elements and pronouns, and also the difference between *who*- and *which*-questions, the following can be stated: For reflexives (e.g. *The woman*$_i$ *is washing [herself*$_i$*]*) and *who*-questions (e.g. *Who is pushing the man?*) only narrow syntax is needed. The relation between a reflexive and its antecedent can be established within the sentence, by narrow syntax. Likewise, the question word *who* does not refer to a specific referent. However, for object pronouns (e.g. *The woman*$_i$ *is washing [her*$_j$]) and referential *which + NP* questions (e.g. *Which woman is pushing the man?*) discourse and access to information structure require additional processing apart from narrow-syntactic processing.

It has been shown that agrammatic speakers perform relatively well on sentences with reflexives and on *who*-questions (see for example Avrutin, 2000, 2006, and the cited references therein). The scope of narrow syntax is only the sentence; hence, processing at the level of narrow syntax does not require much resource capacity. However, agrammatic speakers' performance on comprehending object pronouns and *which + NP* questions is often impaired. This is consistent with the so-called processing deficit account such as the one by Caplan, Waters, DeDe, Michaud, and Reddy (2007): Agrammatic individuals lack sufficient resources to successfully perform several syntactic operations simultaneously due to limited working-memory capacities.

Recently, the theory on impaired discourse-linking in agrammatic aphasia (Avrutin, 2006) has been combined with the idea from theoretical linguistics that past tense is discourse-linked (Zagona, 2003). Tense is a morphological inflection on the verb that provides information about the temporal relation, such as 'simultaneity' or 'precedence,' between the time interval of the event and the time of evaluation set by the context. Bastiaanse et al. (2011) expanded on Zagona's and Avrutin's theory and hypothesized that past time reference is discourse-linked, regardless of the tense used.[2] Agrammatic speakers find it more difficult to produce and comprehend verb forms that refer to the past than verb forms that refer to the non-past, because of their difficulties with discourse linking, which is captured by the Past DIscourse LInking Hypothesis (PADILIH; Bastiaanse et al., 2011; Bastiaanse, 2013). The PADILIH predicts

[2] For example, in English and Dutch one can refer to the past by using the present perfect: A verb form with an auxiliary in present tense that as a whole refers to the past. Such forms were also impaired compared to present time reference (Bos & Bastiaanse, 2014)

that verb forms with past time reference, such as 'wrote', are impaired in agrammatic aphasia, because they are discourse-linked: In order to interpret a verb with past time reference, a link has to be made to an event time. Also non-brain-damaged speakers (NBDs) require more resources to process past time reference than to process non-past time reference. Verb forms with non-past time reference,[3] such as 'writes', are relatively spared, because they can be processed by narrow syntax alone.

One of the issues in aphasiology is to what extent comprehension problems are specific to a particular syndrome. In non-brain-damaged people evidence for the linguistic complexity of past time reference comes from studies in which (discourse-related) electrophysiological differences in processing of past and non-past time reference violations have been found, which are related to discourse-processing (Dragoy, Stowe, Bos, & Bastiaanse, 2012) and not tense (Bos, Dragoy, Stowe, & Bastiaanse, 2013).

Also for people with fluent aphasia, discourse-linked past time reference requires additional processing. Production studies showed they could still refer to the past; however, they tend to resort to less complex verb forms with non-finite lexical verbs, such as 'has written.' Furthermore, agrammatic speakers are overall less consistent in assigning the correct time reference than fluent aphasic speakers (Dragoy & Bastiaanse, 2013; Bos & Bastiaanse, 2014). Cho-Reyes and Thompson (2012) found that although syntactic abilities in fluent (anomic) aphasia are largely preserved, more complex forms of verbs and sentences are impaired. Processing of discourse-linked elements by fluent aphasic individuals in other domains has not been sufficiently addressed yet. Only a few studies with fluent aphasic participants reported on the performance in the domain of *who*- and *which*-questions (Wimmer, 2010) or in the pronominal domain (Grodzinsky, Wexler, Chien, Marakovitz, & Solomon, 1993; Love, Nicol, Swinney, Hickok, & Zurif, 1998; Ruigendijk & Avrutin, 2003) and no clear pattern emerged.

We investigated the processing of discourse-linked elements in both agrammatic and fluent aphasia in the domains of time reference, *wh*-questions, and pronouns. In the following paragraphs, we review the literature on comprehension of discourse-linked elements in aphasia with a focus on these three

[3] Aronson (1977), Partee (1973), and Zagona (2013) proposed that future tense should be seen as a sub-class of present tense. They assume it is derived from the present tense via modal and aspectual features. This view is adopted here by distinguishing between past and non-past time reference.

domains. Subsequently, we provide the relevant linguistic background on Russian, the language under study, before describing the aims of our experiments.

2.1.2 Previous studies on discourse-linked elements in aphasia

In studies on agrammatism, there is cross-linguistic evidence that supports and further refines the PADILIH. Bastiaanse et al. (2011) report data from the Test for Assessing Reference of Time (TART: Bastiaanse, Jonkers, & Thompson, 2008), which has a binary choice task for testing comprehension. In languages with a simple verb inflection paradigm (English) and more extensive verb inflection paradigms (Turkish) as well as in a language that uses freestanding grammatical morphemes for time reference (e.g. aspectual adverbs in Chinese), the pattern of reference to the past (through grammatical morphology) being more impaired than reference to the non-past emerged. The TART was also used to test an agrammatic aphasic group of Swahili-English bilinguals. They were more impaired in reference to the past than to the non-past in production and comprehension in both languages.

There are a number of grammaticality judgment studies in which the congruency of the temporal adverb and the verb's time reference was manipulated. No clear pattern has emerged from such studies. Stavrakaki and Kouvava (2003) reported near-ceiling performance for time reference violations by verbs with past time reference (expressed by past tense). Clahsen and Ali (2009) and Mészáros (2011) reported no difference between time reference violations by verbs with past time reference (expressed by past tense) and present time reference (expressed by present tense), and also the data from Greek agrammatism by Nanousi, Masterson, Druks, and Atkinson (2006) did not yield a particular pattern of time reference errors. Faroqi-Shah and Dickey (2009) found that agrammatic speakers of English responded faster to time reference violations by a verb with present time reference, than by a verb with past or future time reference, although the accuracy did not differ. These reaction time experiments seem to give more information than grammaticality judgment. However, if errors are made on such a task, it is unclear whether these are due to insufficient processing of the time reference of the verb, of the adverb, or of both. Thus, such studies are not very revealing concerning differences between time frames; they merely suggest that the time reference per se is problematic for an aphasic population.

Relatively few studies investigated time reference processing in fluent aphasia. In spontaneous speech of fluent aphasic speakers there are, to our knowledge, no reports of a marked deficit for past time reference, however, in an experimental setting, fluent aphasic speakers showed a quantitatively and qualitatively impaired performance on verbs with past reference compared to non-past reference (for production: Bos & Bastiaanse, 2014; Dragoy & Bastiaanse, 2013; Kljajevic & Bastiaanse, 2011; Wieczorek, Huber, & Darkow, 2011; for production and comprehension: Jonkers & de Bruin, 2009). Two production studies with the TART have revealed that the problems with time reference do not surface similarly in agrammatic and fluent aphasic speakers, as reflected in an error analysis. Although the quantitative accuracy was the same in the two groups, agrammatic speakers were overall less consistent than fluent aphasic speakers in assigning temporal reference to verbs (Bos & Bastiaanse, 2014; Dragoy & Bastiaanse, 2013). Jonkers and de Bruin (2009) investigated comprehension of time reference in a group of five agrammatic speakers and seven speakers with Wernicke's aphasia in Dutch. Overall, past time reference (expressed by the simple past) was more difficult than non-past time reference (expressed by the simple present), with no difference for high or low frequency verbs.

Several studies have shown that *who*- and *which*-subject questions represent a similar dichotomy.[4] Hickok and Avrutin (1996) investigated processing of *wh*-questions in two agrammatic speakers and found that comprehension of *which*-subject questions was impaired, while comprehension of *who*-subject questions was relatively spared. Similar results have been reported by Salis and Edwards (2008). Data from languages with a strong case system are also available, in which grammatical role assignment depends on the case (e.g., nominative and accusative case) of the noun phrase. Word order is less rigid. Neuhaus and Penke (2008) collected comprehension data from agrammatic speakers of German. With implicational scaling they show that *who*-subject questions are better preserved than *which*-subject questions.

However, other studies showed no difference between *who*- and *which*-questions, both being processed at ceiling in agrammatic aphasia. Stavrakaki and Kouvava (2003) had two agrammatic speakers of Modern Greek perform a grammaticality judgment task in which movement of *wh*-operators was manipulated.

[4] Some studies also contained *wh*-object questions. The difference between subject and object questions is out of scope of this paper.

Their participants scored at ceiling on *who*- and *which*-subject questions. Another study on in Modern Greek only focused on *who*-questions about pictures, and also reported ceiling performance (Fyndanis, Varlokosta, & Tsapkini, 2010). Kljajevic and Murasugi (2010) investigated *who*- and *which*-questions in different structures in Croatian, a Slavic language. On an act-out task, most of their agrammatic participants performed at ceiling for direct questions, embedded questions, long-distance questions, and relative clauses, while for passive questions their performance contained considerable variation.

Little is known about *wh*-extraction in fluent aphasia. Cho-Reyes and Thompson (2012) tested a large group of anomic aphasic individuals and found ceiling performance on *who*-subject questions on a sentence-picture matching task. German fluent aphasic speakers tested by Wimmer (2010) comprehended *who*- and *which*-subject questions at chance level, with no significant difference between the two.

A number of experiments tested agrammatic individuals' comprehension of reflexives and pronouns by grammaticality judgment. Some studies report a difference between comprehension of reflexives and pronouns. Grodzinsky et al. (1993) used a picture verification task with sentences of the type: *Is Mama bear touching her/herself?* The authors interpret the results as chance performance for the English agrammatic speakers for the pronoun sentences where the picture did not match.[5] We reanalyzed their data to show that the mean accuracy of agrammatic speakers on sentences with reflexives was 90.2% and on pronouns was 63.5%. Ruigendijk, Vasić, and Avrutin (2006) tested Dutch agrammatic speakers with a ternary choice picture-sentence matching task. The individuals with aphasia performed significantly worse than the non-brain-damaged participants on pronouns, but not on reflexives. In a follow-up experiment they compared pronouns and reflexives in Exceptional Case Marking constructions of this kind: *... en daarna zag de man*$_i$ *zichzelf*$_{i/*j}$ / *hem*$_{*i/j}$ *voetballen*: '...and then the man$_i$ saw himself$_{i/*j}$ / him$_{*i/j}$ play soccer'. Here, the performance on pronouns was significantly worse than the performance on

[5] We investigated the possibility that the agrammatic and fluent aphasic participants in Grodzinsky et al.'s study had a yes bias, which may lead to a better score for the pronoun sentences where the picture matched. We reanalyzed their data with A', a technique to take out a bias in yes/no-answers (Grier, 1971). The conclusion that Grodzinsky et al. (1993) drew, that the fluent and agrammatic aphasic groups show a very different performance pattern can be refined: In their study, both aphasic groups performed worse on pronoun conditions as compared to reflexive conditions (Wilcoxon's test: $W = 95$, $p <.002$), but their error patterns are different, because the agrammatic speakers exhibited a yes-bias.

reflexives.

Other studies have not reported any difference between comprehension of reflexives and object pronouns. Edwards and Varlokosta (2007) performed an experiment with English agrammatic speakers similar to the one by Grodzinsky et al. (1993) and report overall chance performance on mismatch conditions. They conclude that in agrammatic comprehension both reflexives and pronouns are impaired, but on the basis of their experiment they cannot tell whether this is due to the same underlying disorder. Martínez-Ferreiro (2010) used a binary choice sentence-picture matching test to investigate comprehension of object versus reflexive clitics in agrammatic speakers of Ibero-Romance languages. Overall performance was at ceiling, without significant differences between conditions.

Love et al. (1998) conducted an online priming paradigm experiment in which the activation of the referent of either a pronoun or a reflexive was measured. Sentences were of the type *The boxer*$_i$ *said that the skier*$_j$ *in the hospital had blamed him*$_i$*/himself*$_j$ *for the recent injury.* At the point of *him/himself*, priming of the subject-NP of the embedded sentence (*skier*) was investigated. The healthy control group correctly showed a priming effect for *skier* at *himself*, and not at *him*. However, the three individuals with Broca's aphasia showed no priming for *skier* at *himself*, and incorrect priming for *skier* at *him*. Hence, not only did the reflexive not yield a priming effect for its referent skier, but also the pronoun incorrectly elicited activation for the *skier*. This study suggests that the processing of both pronouns and reflexives is impaired in agrammatism.

Fewer studies investigated pronominal and reflexive reference in fluent aphasia. Data from a sentence-picture matching task in Dutch with two fluent aphasic participants suggested a general problem with referential elements (Ruigendijk & Avrutin, 2003). Grodzinsky et al. (1993) administered their picture verification task to a group of individuals with Wernicke's aphasia, who scored at chance level for matching and non-matching pronoun conditions. Our reanalysis of these data confirmed that the fluent aphasic individuals understood reflexives (96.9% accuracy) better than pronouns (69.7% accuracy). The priming effect study by Love et al. (1998) also included English-speaking participants with Wernicke's aphasia. These participants behaved similarly to healthy participants: at the reflexive, they showed correct priming of the corresponding antecedent, which was absent when a pronoun was encountered.

In sum, there is cross-linguistic evidence that in agrammatic and fluent aphasia, reference to the past is more vulnerable than reference to the non-past in languages that obligatorily mark time reference on the verb (see Bastiaanse, 2013, for a more extensive review). Verbs demanding discourse-linking require more grammatical computation than verbs that can be processed without discourse-linking. Studies that reported a significant difference between *who* and *which* in agrammatic aphasia, point to an impairment of the latter (Hickok & Avrutin, 1996; Salis & Edwards, 2008; Neuhaus & Penke, 2008), but not all studies found divergent behavior on these structures (Stavrakaki & Kouvava, 2003; Kljajevic & Murasugi, 2010). For fluent aphasic speakers no asymmetric comprehension pattern of *wh*-extracted questions emerged (Wimmer, 2010). Regarding aphasic comprehension of reflexives and object pronouns, no clear pattern has emerged. Some studies on agrammatic aphasia reported worse comprehension of object pronouns than reflexives (Grodzinsky et al., 1993; Love et al., 1998; Ruigendijk, Vasić, & Avrutin, 2006), although in other studies both types of anaphora were impaired (Edwards & Varlokosta, 2007) or spared (Martínez-Ferreiro, 2010). Previous research on fluent aphasia does not unequivocally point towards impaired processing of pronouns compared to reflexives either (no impairment: Love et al., 1998; overall impairment: Ruigendijk & Avrutin, 2003; pronouns processing worse than reflexives: Grodzinsky et al., 1993).

2.1.3 Linguistic background of Russian

In Russian, time reference is conveyed through verb inflections for tense and is closely related to a verb's aspect. A distinction is made between past, present and future verb forms, and each verb falls into one of two aspectual categories: perfective or imperfective. There is no unique way to form one aspectual form from another, although some rules can be applied. Aspectual counterparts of a verb are therefore assumed to be different lexical entries and have different lemmas in the dictionary. There is a particular correspondence between time reference and aspect in Russian: simple perfective verb forms may refer to the past or the future, while simple imperfective verb forms refer to the past or present. For past reference, the verbs receive a suffix −*l*- and gender and number marking on the verb stem, for example, past imperfective *pisa-l*: 'he was writing', and past perfective *napisa-l*: 'he wrote'. The present imperfective is formed with number and case marking on the verb stem, for example, *pish-et*: 's/he is writing'. Future perfective requires the same inflection as present imperfective, but added to a perfective verb stem: *napish-et*: 's/he will write'. For a more extensive background on the Russian tense/aspect system, see Dragoy and Bastiaanse (2013). Based on their Russian production data by agrammatic and fluent aphasic speakers, the authors argue that in Russian the prototypical form for past time reference is the past perfective; that is, perfective aspect prototypically denotes completed, past events. Imperfective aspect primarily refers to ongoing, non-past events. The prototypical form for non-past time reference is, therefore, the present imperfective. Comprehension of these prototypical forms will be studied in the current time reference experiment.

For the *wh*-experiment, we used the unmarked word order for *wh*-subject questions. The basic word order of Russian is Subject-Verb-Object (SVO), although the major sentence constituents can be put in any order when it is pragmatically adequate (Bailyn, 1995). *Wh*-subject question words are in nominative case, and *which*-question words are gender marked: *kto*: 'who', and *kakoj/kakaja*: 'which'. Thematic role assignment relies on morphology rather than on the specific syntactic positions: compare, e.g., *kakoj muzhchina presledujet zhenschinu?*: 'which-NOM man-NOM chases woman-ACC' and *zhenschinu presledujet kakoj muzhchina?*: 'woman-ACC chases which-NOM man-NOM', both translated as 'which man is chasing the woman?'.

Reflexive reference is expressed in Russian as the *-s'a* particle (suffix) on the verb, which is not inflected for gender, number or case: *myt'-s'a*: 'wash himself/herself'. Pronominal reference, however, is made with a separate personal pronoun, which is gender-, number- and case-marked: *jego*: 'him', and *jejo*: 'her'; e.g., *myt' jego/jejo*: 'wash him/her'.

2.1.4 Goals of the study

The theory of discourse-linking (Pesetsky, 1987) applies to different domains. If there is an overall impairment of discourse-linking in agrammatic aphasia, as hypothesized by Avrutin (2000, 2006), and if past time reference is indeed discourse-linked, as stated in the PADILIH, then discourse-linking should the common denominator of the deficits in time reference, *wh*-questions, and object pronouns. Until now, this has not been investigated within the same population. Our first goal is to systematically investigate the influence of discourse-linking in these three linguistic domains.

We have previously shown that discourse-linking negatively affects fluent aphasic production on the TART (Bos & Bastiaanse, 2014; Dragoy & Bastiaanse, 2013). In parallel, we expect that the additional processing in discourse syntax that is necessary for discourse-linking will increase the error rate in fluent aphasic comprehension. Our second goal is to compare comprehension of discourse-linked elements in two different aphasic populations: agrammatic and fluent.

2.2 Materials and methods

2.2.1 Participants

There were three participant groups: 10 NBDs, 10 individuals suffering from non-fluent agrammatic aphasia (A1 to A10) and 10 individuals suffering from fluent aphasia (F1 to F10). A certified clinical psychologist diagnosed the aphasic participants using Luria's Neuropsychological Investigation (Luria, 1966) at the Center for Speech Pathology and Neurorehabilitation, Moscow. The agrammatic participants had efferent aphasia (roughly equivalent with Broca's aphasia) and/or dynamic aphasia (a disruption in converting internal speech into spoken utterances; to some degree similar to transcortical motor aphasia), in some cases accompanied by afferent aphasia (roughly equaling apraxia of speech). In the subtests of the neuropsychological investigation targeting sentence construction and spontaneous speech, all participants belonging to this group were diagnosed as agrammatic (effortful, non-fluent speech with errors in inflection, omission of function words combined with relatively good auditory comprehension). They demonstrated effortful, telegraphic, non-fluent speech with relative intact comprehension. The fluent aphasic speakers all had sensory aphasia (roughly corresponding to Wernicke's aphasia), which was in some cases accompanied by acoustic-mnestic aphasia (with the main deficit expressed as anomia and problems with retention of acoustic verbal traces). Their speech output was fluent with word-finding difficulties, verbal and phonemic paraphasias, and their comprehension was impaired.

All brain-damaged participants were aphasic due to a single left-hemisphere stroke except for A5 and F8, who suffered traumatic brain injury, and A3, A6, and F5, who suffered a second stroke. All participants were right-handed and had normal or corrected-to-normal vision, and no hearing problems. Russian was their native language. The mean age of the NBDs was 43.9 (range: 22-74, SD = 15.7), of the agrammatic speakers 43.5 (range: 35-66, SD = 9.7), and of the fluent speakers 55.2 (range 22-68, SD = 13.1). A one-way ANOVA shows no significant difference in age between the three groups ($F(2{,}29) = 2.60$, $p = .09$). In Appendix A.1, the individual participant characteristics are given.

2.2.2 Materials

To investigate the discourse-linked and locally-bound elements conveying time reference, *wh*-reference and pronominal reference, three subtests with similarities in their design were administered to the participants. The order of the items within the test was pseudo-randomized so that no more than three subsequent trials where of the same condition and target gender. Position of the target was balanced across conditions.

For comprehension of time reference, the *Test for Assessing Reference of Time* (TART: Bastiaanse, Jonkers & Thompson, 2008; see Bastiaanse et al., 2011, for more background on this test) was employed. The TART comprehension subtest used in the current study consisted of 20 transitive action verbs in two conditions, so 40 items in total.[6] Each item contained a simple verb form: the past perfective (prototypical form for past time reference in Russian), and the present imperfective (prototypical form for present time reference in Russian). Every sentence consisted of three words: the subject (man or woman), the verb and the object, for example *muzhchina rv'ot bumagu*: (lit. man-NOM tears paper-ACC) 'the man is tearing paper' and *muzhchina porval bumagu*: (lit. man-NOM tore paper-ACC) 'the man tore paper'. A complete list of the verbs used in the test is given in Appendix A.2. Interpretation of the time reference relied on the verb's aspect and its tense morphology. The comprehension TART is a binary choice task. Two color photographs were available per verb, one showing the action being finished and one showing it going on. The two photos were presented above each other. An example of an item is given in Figure 2.1 at the left.

For comprehension of *wh*-questions, a test was developed in analogy with the TART: the *WH-Extraction Assessment Test* (WHEAT). This test investigated subject questions with *who* and *which*. The WHEAT consisted of 20

[6] The TART contained a third condition (with 20 items) for a different research question on prototypicality in time reference (see Dragoy & Bastiaanse, 2013). This condition was the Future Perfect. We will report on the results in a later paper.

TART WHEAT RePro

Figure 2.1: Examples of Russian test items. Left: an example of the TART (*target: muzhchina rv'ot bumagu*: (lit. man-NOM tears paper-ACC) 'the man is tearing paper'). Middle: an example of the WHEAT (target: *kto nes'ot zhenschinu?*: (lit. who-NOM carries woman-ACC) 'who is carrying the woman?'). Right: an example of the RePro (*target: zhenschina katajets'a*: (lit. woman-NOM karts-REFL) 'the woman karts herself').

verbs used in two conditions, 40 items in total.[7] The two types of *wh*-phrases were in nominative case: *kto*: 'who-NOM', and *kakoj muzhchina/kakaja zhenschina*: 'which man/which woman-NOM'. Every sentence consisted of three constituents: the *wh*-phrase, the verb and an object noun (man or woman), for example, *kto nes'ot muzhchinu*? (lit. 'who-NOM carries the man-ACC?'): 'who is carrying the man?' and *kakoj muzhchina nes'ot zhenschinu*? (lit. 'which man-NOM carries the woman-ACC?'): 'which woman is carrying the man?' A complete list of the verbs is given in Appendix A.2. The *wh*-phrases referred to a single person. Therefore, the participant was asked to point to one particular person in the two contrasting color pictures. Four models were used to create two picture-pairs: one showed the action being performed by a man to a woman, and one showed the action being performed by another

[7]The WHEAT contained two more conditions (with 20 items each) for a different research question on the difference between subject and object wh-questions (as for example reported in Hickok & Avrutin, 1996). This research question is out of scope of the current paper.

woman to another man. The person performing the action was always on the left side. An example of an item is given in Figure 2.1 in the middle.

For comprehension of pronominal reference, a test was developed in analogy with the TART and WHEAT: the *Test for Reflexives and Pronouns* (RePro). The RePro consisted of 20 verbs used twice (once with male and once with female actors) in two conditions (reflexive and pronoun), so 80 items in total. The verbs could all be used as a reflexive verb, with the reflexive suffix *−s'a*, and with an object pronoun (*jego*: 'him', or *jejo*: 'her'). Every sentence consisted of two or three words: the subject (man or woman), the verb (with the reflexive suffix for the reflexive condition) and the object pronoun, for example *zhenschina katajets'a*: (lit. woman-NOM karts-REFL): 'the woman karts herself' or *zhenschina katajet jejo*: (lit. woman-NOM karts her-ACC): 'the woman karts her'. A complete list of the verbs is given in Appendix A.2. In the RePro, participants had to choose between two contrasting color photographs: one showing the action being performed to another person of the same gender, and one showing the action being performed to the acting person himself/herself, where a second person appeared passively in the picture. The acting person was always on the left side, and the passive person on the right. An example of an item is given in Figure 2.1 at the right.

2.2.3 Procedure

For the three tests, the experimenter showed a pair of two pictures to the participant and read a sentence aloud. The participant was asked to point to the photograph (or, in case of the *wh*-questions, to the person) matching the sentence. The TART began with two practice items with the verbs 'to read' and 'to write', which were repeated until the participant understood the task: *muzhchina chitaet pis'mo*: (lit. man-NOM reads letter-ACC) 'the man is reading the letter', and *muzhchina napisal pis'mo*: (lit. man-NOM wrote letter-ACC) 'the man wrote the letter'. For the WHEAT, the practice items contained the verbs 'to massage' and 'to feed': *kto massazhirujet zhenschinu?*: (lit. who-NOM massages the woman-ACC?) 'who is massaging the woman?' *kakaja zhenschina kormit muzhchinu?*: (lit. which woman-NOM feeds man-ACC?) 'which woman is feeding the man?' The participant was asked to point to a particular person in the photo. For the RePro, there were four practice items that contained the verb 'to shave' for the male actors and 'to make up' for the female actors: *muzhchina brejet ego*: (lit. man-NOM shaves him-ACC) ‘the man is shaving him’ and *zhenschina krasits’a*: (lit. woman-NOM makes-up-REFL) ’the woman is making herself up’. When the participant pointed to the wrong picture, the sentence matching that picture was contrasted with the probe sentence. On experimental items, no feedback was given. Responses were scored as correct when the participant pointed to the target picture. If the participant asked for more than one repetition, the response was counted as incorrect. The TART was always administered first, and the WHEAT was always administered last.

2.2.4 Data analysis

To test for an overall reliable difference between NBDs and the two aphasic groups, a linear mixed-effects regression analysis was carried out using the *lmer* function of the *lme4* package (Bates, Maechler, & Bolker, 2013) and Tukey’s contrasts from the *glht* function of the *multcomp* package (Hothorn et al., 2013) in R (R Core Team, 2013). The dependent variable of the model was log-linked accuracy (1 = correct, 0 = incorrect) with random effect factors for Participant and Item. A separate model was developed to investigate differences between conditions and aphasic groups. This model contained the fixed effects Aphasia type (agrammatic/fluent), Test (TART/WHEAT/RePro), Discourse-linking (yes/no) with a three-way interaction and the fixed effect Trial number. There were random-effect factors for Participant and Item with random slopes for Trial number, Test and Discourse-linking per Participant, and a random slope for Discourse-linking per Item. The model was developed by excluding insignificant parameters from a full model containing Aphasia type, Test, Discourse-linking, and Trial number with interactions between them as fixed factors. There were also interactions between Trial number, Test and Discourse-linking per Participant as random slopes and Discourse-linking by Item as random slope. Model comparison was based on the Akaike Information Criterion (AIC) and log likelihood ratio tests (significance defined as $p < .05$).

2.3 Results

In Figure 2.2, the mean accuracy on the three tests is given for the two aphasic groups. Individual scores can be found in Appendix A.3.

The NBDs scored at ceiling; no errors were made on any test. The ac-

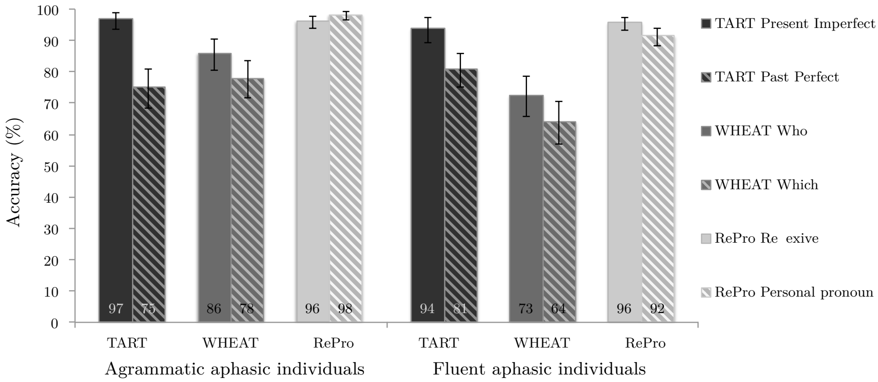

Figure 2.2: Accuracy per subtest for the agrammatic and fluent aphasic speakers. Note that the dashed bars denote discourse-linked conditions.

curacy of the agrammatic and fluent aphasic speakers was significantly lower than the accuracy of the NBDs (β = 6.30, $SE = 1.19$, $z = 5.31$ and $\beta = 6.97$, $SE = 1.18$, $z = 5.88$, respectively). The data of NBDs will be further ignored. The fluent and agrammatic speakers' overall accuracy did not differ ($\beta = 0.\ 67$, $SE = 0.34$, $z = 1.98$). There was a three-way interaction between the factors of Aphasia group, Test, and Discourse-linking (model with a three-way interaction versus a model without an interaction with a) Aphasia type: $\chi^2\,(5) = 24.30$, $p < .001$, with b) Test: $\chi^2\,(6) = 29.91$, $p < .001$, and with c) Discourse-linking: $\chi^2\,(5) = 26.93$, $p < .001$). In order to interpret this interaction, the data were broken down along the variable of Aphasia type, while keeping the remaining model the same and with both models including the variables of Test and Discourse-linking.

In the analysis of agrammatic speakers, there was an interaction between the variables Test and Discourse-linking (model with a two-way interaction versus a model without an interaction: $\chi^2\,(2) = 5.17$, $p > .05$, with a lower AIC for the model including the interaction). In order to interpret this interaction, the three tests were analyzed separately.[8] On the TART, agram-

[8]During the instruction of the WHEAT, agrammatic aphasic participant A3 was still not able to point to the target referent after several repetitions of the practice items. We continued with the experimental items because we hoped she would start understanding the test. We included her data in the final analyses, however, an analysis without her data of the WHEAT did not yield different results.

matic individuals scored significantly lower on the discourse-linked past perfective than on the non-discourse-linked present imperfective ($\beta = 3.02$, $SE = .64$, $z = 4.69$). On the WHEAT, agrammatic speakers scored significantly lower on the discourse-linked *which*-condition than on the non-discourse-linked *who*-condition ($\beta = 1.88$, $SE = .83$, $z = 2.29$). On the RePro, there was no significant discourse-linking effect (model with versus model without the fixed factor of Discourse-linking: $\chi^2\,(1) = 0.004$, $p > .05$, with a lower AIC for the model without Discourse-linking), explaining the two-way interaction. This can also be seen in Figure 2.2: discourse-linking played no significant role in the agrammatic speakers' accuracy on the RePro, where scores were at ceiling.

For the fluent aphasic speakers, there was no significant interaction between Test and Discourse-linking (model with a two-way interaction versus a model without an interaction: $\chi^2\,(2) = 2.00$, $p > .05$, with a lower AIC for the model without the interaction). Tukey's contrast showed that the three tests differed significantly from one another, with the highest accuracy on the RePro and the lowest accuracy on the WHEAT (TART vs. RePro $\beta = 1.43$, $SE = 0.40$, $z = 3.60$, WHEAT vs. RePro $\beta = 3.00$, $SE = 0.57$, $z = 5.22$). Furthermore, on all three tests discourse-linked conditions were more difficult than non-discourse-linked conditions (model with versus model without the fixed factor Discourse-linking $\chi^2\,(1) = 6.23$, $p < .05$). This explains the three-way interaction in the model combining both aphasia types.[9]

2.4 Discussion

With the current study we aimed to investigate whether the problems with *which*-questions, past time reference and pronominal reference are caused by the same underlying disorder, that is, a problem with processing discourse-linked elements. Second, we compared comprehension of discourse-linked elements in agrammatic and fluent aphasic speakers.

Our first prediction, that discourse-linking is impaired in the three investigated domains, was supported by the tests outcomes. In the domain of time reference, the TART showed that past was more impaired than present in both

[9] We performed the accuracy analysis in a sample of participants with stroke-induced aphasia only (9 agrammatic aphasic participants and 9 fluent aphasic participants) and the results were identical to the analysis in which the TBI patients were included. Including age as a predictor did not change the results either.

aphasic groups, in line with previous studies (Abuom & Bastiaanse, 2013; Bastiaanse, 2008; Bastiaanse et al., 2011; Dragoy and Bastiaanse, 2013, Faroqi-Shah & Dickey, 2009; Jonkers & de Bruin, 2009; Nanousi et al., 2006; Stavrakaki & Kouvava, 2003, but no difference was found in grammaticality judgments in Clahsen & Ali, 2009; Mészáros, 2011; Nanousi et al., 2006; Stavrakaki & Kouvava, 2003). In the domain of wh-subject questions, the WHEAT revealed that *which*-questions were more difficult than *who*-questions, which aligns with previous results by Hickok and Avrutin (1996), Neuhaus and Penke (2008), and Salis and Edwards (2008), but no such difference was found by Stavrakaki and Kouvava (2003) and Kljajevic and Murasugi (2010). The RePro, however, only revealed a discourse-linking effect in the fluent aphasic group and was not sufficiently sensitive to demonstrate what problems the agrammatic participants experience in the pronominal domain. Previous studies have not shown a clear pattern in this domain either. Some studies showed impaired comprehension of pronouns and relatively intact comprehension of reflexives (i.e., the bias-corrected scores of Grodzinsky et al., 1993; the incorrect priming of pronouns versus the null-effect on reflexives in agrammatic individuals in Love et al., 1998; the Dutch agrammatic individuals in Ruigendijk, Vasić, and Avrutin, 2006). However, other studies showed impaired comprehension overall (in agrammatic aphasia: Edwards & Varlokosta, 2007; in fluent aphasia: Ruigendijk & Avrutin, 2003).

The results support the idea of Avrutin (2000, 2006) that comprehension of discourse-linked elements is impaired in agrammatic aphasia. It requires extra grammatical processing, which is more demanding for the system compared to processing structures that involve only narrow syntax operations. As computational load increases, errors do so as well, according to processing accounts such as the one by Caplan et al. (2007). More errors are made when the sentence is more complex, because processing by discourse syntax breaks down, and the difference between non-discourse-linked and discourse-linked conditions on a certain test become proportionally larger.

Our second aim was to compare agrammatic and fluent aphasic comprehension of discourse-linked elements. Our results show that also in fluent aphasia, comprehension of discourse-linked elements causes difficulties, as demonstrated by the results of the TART, WHEAT, and RePro. Jonkers and de Bruin (2009) reported similar results in the domain of time reference for agrammatic and fluent aphasia. In the domain of *wh*-subject questions, a previous comprehension study showed no influence of discourse-linking for fluent aphasic participants, but chance level performance in both *which*-subject questions and *who*-subject questions (Wimmer, 2010).

In the pronominal domain, the results of agrammatic and fluent aphasic speakers differ. The interaction we found in the overall analysis pointed to a lacking effect of discourse-linking in the agrammatic aphasic speakers, although we did find statistical evidence for such an effect in the fluent aphasic group. Closer inspection of the data shows, however, that both aphasic participant groups scored near ceiling on this test. As in agrammatic aphasia, previous research on fluent aphasia does not unequivocally point to impaired processing of pronouns compared to reflexives (no impairment: Love et al., 1998; overall impairment: Ruigendijk & Avrutin, 2003; pronoun impairment: Grodzinsky et al., 1993). The combined evidence of our current study and previous studies makes it difficult to draw a conclusion with regards to the influence of discourse-linking on pronominal reference.

The PADILIH (Bastiaanse et al., 2011) was originally based on data from agrammatic aphasia. We found support for a distinction between non-past and past time reference in NBDs as well (Bos et al., 2013; Dragoy et al., 2012). Our current results have implications for this hypothesis, too. In agrammatic aphasia, past time reference difficulties are a central deficit, affecting both production and comprehension (Bastiaanse et al., 2011). Jonkers and de Bruin (2009) reported problems with comprehension of past time reference compared to non-past time reference in Dutch agrammatic and fluent aphasic individuals. Previous experiments show that also in fluent aphasic production, verb forms that require discourse-linking, that is, verb forms referring to the past, cause more difficulties than verb forms for which no such linking is needed; that is, verb forms referring to the present (Bos & Bastiaanse, 2014; Dragoy & Bastiaanse, 2013; Kljajevic & Bastiaanse, 2011; Wieczorek et al., 2011). Hence, the past time reference deficit is central in both types of aphasia, extending the scope of the PADILIH to fluent aphasia.

The patterns of impairment are similar in the agrammatic and fluent aphasic group. However, that does not mean that the underlying disorder is the same. Earlier research has shown that fluent aphasic individuals often show a similar qualitative performance, but the underlying deficit can nonetheless differ from that of agrammatic aphasic individuals (Balogh & Grodzinsky, 2000; Bastiaanse & Edwards, 2004; Bastiaanse, 2011). Analysis of production errors on verb morphology for time reference showed that agrammatic aphasic speakers more often switch to another time frame than fluent aphasic speakers (Dragoy & Bastiaanse, 2013; Bos & Bastiaanse, 2014). We believe other methods should be used to investigate whether the problems with comprehension of discourse-linked elements stem from a different underlying disorder in agrammatic and fluent aphasia. We are currently performing an eye-tracking experiment that can potentially illuminate this issue.

CHAPTER 3

Time reference decoupled from tense in aphasia[1]

Abstract — *Background*: Reference to an event's time frame can be accomplished through verb inflection. In agrammatic aphasia, a deficit in past time reference has been identified by Bastiaanse et al. (2011). In fluent aphasia, specific problems with this time frame (expressed by the past tense) have been found as well (Dragoy & Bastiaanse, 2013; Jonkers & de Bruin, 2009). However, 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').

Aims: The goal of this study is twofold. First, it aims to untangle tense problems from problems with past time reference through verb morphology in people with aphasia. Second, this study aims to compare the production of time reference inflection by people with agrammatic and fluent aphasia.

Methods & Procedures: 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

[1]This chapter was adapted from: Bos, L.S., & Bastiaanse, R. (2014). Time reference decoupled from tense in agrammatic and fluent aphasia. *Aphasiology, 28*, 533-553.

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 (NBDs) took part in this study. Data were analyzed quantitatively and qualitatively. *Outcomes & Results*: NBDs 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.

Conclusions: 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.

3.1 Introduction

Verb inflection is notoriously difficult for individuals with agrammatic speech. Spontaneous speech analysis as well as experimental testing has demonstrated that finite verb forms (those forms that correspond in number and person with the subject of the sentence) are difficult to produce for them (Burchert, Swoboda-Moll, & De Bleser, 2005; Clahsen & Ali, 2009; Friedmann & Grodzinsky, 1997; Gavarró & Martínez-Ferreiro, 2007; Kok, Kolk, & Haverkort, 2006; Kok, van Doorn, Kolk, 2007; Wenzlaff & Clahsen, 2004, 2005; Wieczorek, Huber, & Darkow, 2011). Even though many reasons for this phenomenon have been proposed, most researchers agree that tense and aspect, the inflectional forms that are used to set the time frame of the event, are difficult to produce (e.g., Clahsen & Ali, 2009; Friedmann & Grodzinsky, 1997; Gavarró & Martínez-Ferreiro, 2007; Kok et al., 2006; Kok et al., 2007; Wenzlaff & Clahsen, 2004, 2005; Wieczorek et al., 2011), although in some studies agreement has found to be equally, or more impaired (e.g., Burchert et al., 2005; Lee, Milman, & Thompson, 2008). This raises several questions. The first is: why is it so difficult to inflect a verb for tense and aspect and not for agreement? Another question is: are these tense and aspect problems restricted to agrammatic speakers or do all aphasic speakers encounter problems with these grammatical morphemes? In order to answer these questions, one should investigate aphasic verb production in a large variety of languages, since different languages employ different ways to express the time frame of an event through grammatical morphology. The current study addresses two questions on time reference: (1) Do aphasic speakers have a past time reference deficit, irrespective of tense? And (2) are the performance and error patterns of agrammatic and fluent speaking aphasic individuals on time reference comparable? Before reviewing the literature on this topic in aphasia, we will first describe the linguistic background of time reference.

3.1.1 Linguistic background

Tense is a *morphological* inflection that makes a verb finite, whereas *time reference* is a *semantic* feature of the event being described by the verb phrase as a whole. *Tense* provides information about the temporal relation, such as 'simultaneity' or 'precedence,' between the time interval of the event expressed through the verb morphology and the time of evaluation set by the context. *Aspect* further specifies temporal relations by defining the boundaries (beginning, end point) of a situation, telling whether the event is completed or ongoing. It is the combination of tense, aspect, and context that specifies the time reference, as illustrated below.

In Dutch, like in English, both simple verb forms (finite; with tense and aspect expressed on a single lexical verb) and periphrastic verb forms (consisting of a finite auxiliary plus a lexical verb) can be used to refer to the past, see example (1).

(1a) past tense, imperfect aspect
De man *schreef* *de brief.*
the man wrote$_{\text{past tense}}$ the letter
'The man wrote the letter.'

(1b) present tense, perfect aspect
De man *heeft* *de brief* *geschreven.*
the man has$_{\text{present tense}}$ the letter written$_{\text{past participle}}$
'The man has written[2] the letter.'

In example sentence (1a), the verb is inflected for past tense and it refers to the past. In sentence (1b), however, the auxiliary has present tense inflection but the verb complex [have + participle] refers to the past. There is neurophysiological evidence for this distinction between tense and time reference in non-brain-damaged participants, suggesting that it is not only a theoretical distinction: Bos, Dragoy, Stowe and Bastiaanse (2013) found that brain responses to time reference violations by simple and periphrastic verb forms as in (1a-b) are similar, irrespective of the tense used.

Finite Dutch verbs[3] agree in person (in present tense) and number (in present and past tense) with the subject. The third person simple present in Dutch is formed by adding the suffix $-/t/$ to the stem, for example *werk-t*: 'work$_{\text{present/3sg}}$'. The simple past is formed by adding the suffix $-/te/$ to the stem, followed by the agreement suffix, for example *werk-te*: 'work$_{\text{past/3sg}}$' The periphrastic past consists of an (irregular) auxiliary ('to have' or 'to be') and the past participle, formed with the prefix *ge-* and the suffix $-/t/$, for example *heeft gewerk*t: 'have$_{\text{present/3sg}}$ work$_{\text{past/participle}}$'.

3.1.2 Time reference in aphasia

There are several accounts for the problems with tense inflection in agrammatic aphasia (Burchert et al., 2005; Clahsen & Ali, 2009; Faroqi-Shah & Dickey, 2009; Friedmann & Grodzinsky, 1997; Kok et al., 2006; Nanousi, Masterson, Druks, & Atkinson, 2006; Wenzlaff & Clahsen, 2004, 2005). However, recently it has been shown that the verb inflection problems are also related to the time frame to which is being referred. More specifically, verb forms that refer to the past are more impaired than verb forms that refer to the non-past,[4] both in production and comprehension (Bastiaanse, 2008; Bastiaanse et al., 2011). Based on an extensive review of aphasiological verb production and comprehension data, Bastiaanse et al. (2011) and Bastiaanse (2013) formulated the PAst DIscourse LInking Hypothesis (PADILIH) to describe the pattern of selective impairment of past time reference and relatively spared non-past time reference. The PADILIH claims that reference to the past through verb forms is discourse-linked, regardless of the anaphoric means employed (i.e. not only through tense as suggested by Zagona, 2003). In order to refer to an event in the past, a link has to be made in discourse. The event is then not only processed by narrow syntax, but also by discourse syntax. The scope of narrow

[3]This paragraph is only on regular verbs, since the distinction between regular and irregular verbs is outside the scope of this paper.

[4]Aronson (1977), Partee (1973), and Zagona (2013) suggested that future tense should be seen as a sub-class of present tense, because it is derived from the present tense via modal and aspectual features. This view is adopted here by distinguishing between past and non-past time reference.

syntax is only the sentence; hence, processing at the level of narrow syntax requires less resource capacity and is usually less affected in agrammatic aphasia. Processing discourse syntax requires additional syntactic operations and access to information structure; however, agrammatic individuals lack sufficient resources to apply these operations (Avrutin, 2000, 2006). They fail to perform multiple syntactic operations simultaneously due to limited working memory capacities according to processing accounts such as the one by Caplan, Waters, DeDe, Michaud, and Reddy (2007). Events occurring in the here-and-now of the individual speaking or in the future do not require a discourse link and are, therefore, relatively spared.

During the last couple of years, agrammatic speakers of several languages have been studied to test the PADILIH and the predictions of the PADILIH have been compared with findings from others. The data are summarized below.

3.1.3 Experimental evidence for the PADILIH in agrammatism

There is cross-linguistic evidence supporting and further refining the PADILIH. Yarbay Duman and Bastiaanse (2009) investigated past tense with perfect aspect (e.g., *ütüle-di-m*: 'iron$_{\text{perfect/past-1sg}}$') and future tense with imperfect aspect (e.g., *ütüle-(y)eceğ-im*: 'iron$_{\text{future-1sg}}$') in a sentence completion test in Turkish. In production, Turkish agrammatic speakers experience more problems with a finite verb referring to the past than with a finite verb referring to the non-past. This finding is in line with the proposed distinction between past and non-past.

Bastiaanse et al. (2011) reported data from the Test for Assessing Reference of Time (TART: Bastiaanse, Jonkers, & Thompson, 2008) in languages with a simple verb inflection paradigm (English) and more extensive verb inflection paradigms (Turkish) as well as in a language that uses freestanding grammatical morphemes for time reference (Chinese). The TART is intended for use in many languages and designed for the assessment of time reference expressed by verb forms. It has a production section with sentence-completion (see the 'Material and Methods' section) and a comprehension section with picture-sentence matching. The pattern of past time reference being more impaired than non-past time reference emerged in the production and comprehension sections of the TART for English and Turkish. For Chinese, performance in the production section was low overall and in the comprehension section, past time reference was found to be selectively impaired compared to the present and future.

Bastiaanse et al. (2011) also reanalysed the English data of Lee and colleagues (2008; Experiment 2) taking into account only tense errors while leaving out agreement errors. The reanalysis showed that simple past tense ('he walked') is more difficult than simple present tense ('he walks') and [auxiliary + past participle] ('he has walked') is more difficult than the present progressive ('he is walking'). This suggests that in both languages, past time reference was impaired in finite and non-finite verb forms. Nanousi et al. (2006) tested Greek agrammatic aphasic participants with a range of tasks. The results of two tasks tapping into tense production were mixed: At sentence level (but not at a single word production task), both the past progressive (e.g., *e-graf-a*: 'I was writing') and the simple present were easier than the simple past and the periphrastic future.[5] Accuracy on the periphrastic past perfect was somewhere in between. The participants' performances on the periphrastic future are not in line with the PADILIH, but two other tasks did show the predicted pattern: The aphasic participants had more problems with perfect aspect (tested in past perfect) and perfective aspect (tested in simple past) than with imperfect aspect (tested in simple present).

Abuom and Bastiaanse (2013) tested agrammatic Swahili-English bilinguals with the TART (Abuom & Bastiaanse, 2010). They showed that the agrammatic speakers were more impaired in reference to the past than to the non-past in production and comprehension in both languages, and overall more impaired in English than in Swahili. As in Abuom, Obler, and Bastiaanse (2011), they hypothesize that the difference in performance across the two languages is caused by existence of both regular and irregular verb forms in English, since Swahili has a more complex but very regular inflection paradigm.

In multiple-choice sentence completion and grammaticality judgment studies the congruence of the temporal adverb and the verb's tense is manipulated. No clear pattern has emerged from such aphasiological studies. Stavrakaki and Kouvava (2003) reported near-ceiling performance for time reference violations by the past tense. Clahsen and Ali (2009) reported no difference between time reference violations by verbs in past and present tense, and also the grammaticality judgment data from Greek agrammatism by Nanousi et al. (2006) did

[5] In their paper, Nanousi et al. (2006) use the term 'simple future' for periphrastic future.

not yield a particular pattern of time reference errors. Faroqi-Shah and Dickey (2009) tested agrammatic speakers of English' responses to time reference violations. The participants responded faster to violations by a verb with present time reference, than by a verb with past or future time reference, although the accuracy did not differ. These reaction times seem to give more information than grammaticality judgment. However, if errors are made on such a task, it is unclear whether these are due to insufficient processing of the time reference of the verb's tense, of the adverb, or of both. This shows us that multiple-choice sentence completion and grammaticality judgment are suitable to compare between function categories, but not within. Thus, these tests may not be the best tool to investigate time reference processing in an aphasic population.

3.1.4 Spontaneous speech evidence for the PADILIH in agrammatism

Support for the PADILIH has also been found in spontaneous speech. Simonsen and Lind (2002) published a case study on a Norwegian individual with agrammatic Broca's aphasia. In his spontaneous speech with a non-aphasic interlocutor, he did not produce a single verb referring to the past, but relied on strategies such as writing down a year, relying on the interlocutor, or using a noun or adjective to express temporal reference. A verb elicitation task showed that he was able to inflect verbs for reference to the past (although he made errors). The authors conclude that the lack of verb forms with past reference is processing-related, which is in line with Avrutin (2000, 2006). Stavrakaki and Kouvava (2003) studied the spontaneous speech of two agrammatic speakers of Greek.[6] Both aphasic speakers made errors in contexts requiring the perfective past, producing a present time reference form instead. The errors were more likely to occur in syntactically complex contexts, which is in line with a processing account of agrammatism (e.g., Caplan et al., 2007) and of discourse-linking in aphasia (Avrutin, 2000, 2006). Beeke, Wilkinson, and Maxim (2003) analysed conversational speech of an English agrammatic speaker (plus spouse) and found that in an obligatory context for past and future time reference, the

[6]The authors collected their data in every day conversation that included questions eliciting reference to the past (S. Stavrakaki, personal communication with L.S. Bos, April 24, 2013).

speaker often produced present time reference or an infinitive.[7] Abuom and Bastiaanse (2012) analysed narrative speech of six agrammatic English-Swahili bilinguals. In both languages, reference to the past was impaired compared to the present; however, in English, errors were mainly tense omissions while in Swahili they were mainly tense substitutions.

In Standard Indonesian, verbs are not inflected for tense and agreement. For time reference, aspectual adverbs are used when the time frame of the event is not clear from discourse. These aspectual adverbs have a similar function as verb inflection for tense and agreement in other languages: They denote whether an event is completed, still ongoing, or has yet to commence. However, these aspectual adverbs are only used when the time frame is not clear from the context. Bastiaanse (2013) argues that these aspectual adverbs are, thus, discourse-linked by definition and hence no difference between referring to past, present and future is expected. This is exactly what is reported for Standard Indonesian (Anjarningsih & Bastiaanse, 2011).

Taken together, there is evidence that in agrammatic aphasia, reference to the past is more vulnerable than reference to the non-past in languages with obligatory marking for time reference. Verbs that need discourse-linking require more grammatical computation than verbs that are not discourse-linked. Also, aspectual markers in Standard Indonesian are vulnerable because they require discourse-linking.

As previously stated, there is another unanswered question: Whether these time reference problems are specific for agrammatic aphasia. It has been shown that fluent aphasic speakers also have problems with inflected verbs. Therefore, it is conceivable that these problems are also related to time reference.

3.1.5 Time reference in fluent aphasia

One of the issues in aphasiology is to what extent symptoms are specific to a particular syndrome. Bastiaanse (2011), for example, showed that finite verbs in both agrammatic and fluent aphasic spontaneous speech have low lexical variety compared to healthy speech. This difference is not found in non-finite verbs (infinitives and participles).

Relatively few studies investigated time reference in agrammatic and flu-

[7] If the future is derived from the present via modal and aspectual features, then this is more demanding than the use of present itself. This may account for the substitution of future with present.

ent aphasia. Fluent aphasic speakers experience different and less pronounced problems with tense inflection in spontaneous speech than agrammatic aphasic speakers. However, the finite verbs they use have a higher frequency and a lower diversity than the non-finite verbs, whereas in the spontaneous speech of non-brain-damaged speakers (NBDs) diversity and frequency of finite and non-finite verbs do not differ (Bastiaanse, 2011). Still, in an experimental setting, people with fluent aphasia also show an impaired performance on verbs with past time reference compared to verbs with non-past time reference, which is however qualitatively different from that of agrammatic aphasic speakers (Dragoy & Bastiaanse, 2013; Jonkers & de Bruin, 2009; Kljajevic & Bastiaanse, 2011; Wieczorek et al., 2011). Wieczorek and colleagues (2011) trained two German speaking individuals with Broca's aphasia and two individuals with Wernicke's aphasia in tense and aspect production. All participants made errors during the baseline task, mainly tense (and therewith aspect) substitutions. The authors did not analyse the errors separately per time frame. They conclude that problems with time reference are not limited to agrammatic Broca's aphasia.

Jonkers and De Bruin (2009) tested simple past and present tense in Dutch. Overall the simple past was more difficult than the simple present for both groups, but fluent aphasic speakers made different errors than agrammatic aphasic speakers. The agrammatic speakers most often made tense substitutions (of simple past and simple present) or used infinitives, while the fluent aphasic speakers mostly made tense errors without a specific pattern (two fluent aphasic speakers mainly made substitutions of past tense with present tense.) However, this study did not focus on a possible difference in error patterns separately per target time frame. Furthermore, only the simple past and present were investigated, not the periphrastic past, so that tense cannot be decoupled from time reference in their results.

A Russian study with the TART included an error analysis targeted at time reference, which showed that the problems with time reference do not surface similarly in agrammatic and fluent aphasic speakers (Dragoy & Bastiaanse, 2013). Accuracy on the time reference conditions showed that past forms were more impaired than non-past forms in both groups. The error analysis revealed that both aphasic groups produced non-past time reference instead of the past target. For target present time reference, substitutions with other non-past time reference verb forms were most frequent. Still, agrammatic speakers were overall less successful in providing the appropriate temporal relations. However, past time reference cannot be teased apart from tense in this Russian study.

All in all, these data suggest that problems with reference to the past through verb inflection are not limited to agrammatic aphasia, but exist in fluent aphasia as well. This does not indicate, however, that the underlying problem in these two aphasia types is the same.

3.1.6 Time reference and theory on speech production

According to Levelt (1989), speech production is a modular process. He distinguishes between grammatical encoding and phonological encoding. Grammatical encoding is the process of sentence construction for which information provided by the lemmas of the lexical entries is used. The lemmas activate the lexemes, the underlying phonological word forms that are used for Phonological Encoding. Bastiaanse and Van Zonneveld (2004) used his model to localize the functional deficit in agrammatic aphasia. They argued agrammatic aphasia is a processing deficit and that the production problems are caused by poor grammatical encoding abilities. The more information needs to be encoded, the more prominent the problems will be. It is easy to see how such a deficit can explain the time reference problem in agrammatic aphasia: For reference to the past narrow syntax alone is not enough. It requires discourse-linking, an extra grammatical operation, resulting in poor performance.

In fluent aphasia, the major problem is in retrieving the underlying word forms. It is generally assumed that the word forms are available, but difficult to access. Bastiaanse (2011) argued that word retrieval diminishes when more complex grammatical encoding is needed. This interplay between lexical retrieval and grammatical encoding causes, among others, problems with the production of finite verbs in spontaneous speech. These problems will increase when discourse-linking is required, thus, in cases of verb forms that refer to the past.

3.1.7 Goals of the study

The goal of the current study is two-fold. First, we aim to investigate whether agrammatic and fluent aphasic speakers have problems with verb forms that refer to the past, irrespective of tense. No previous aphasia study has focused on this specific topic. Dutch is a suitable language to investigate this, because past time reference can be conveyed through verb forms in present tense, as explained above. The current study can thus provide more information on the nature of the time reference deficit. The PADILIH (Bastiaanse et al., 2011, Bastiaanse, 2013) is based on data from agrammatic aphasia and predicts that

1. agrammatic speakers will perform relatively poor on verb forms that refer to the past, irrespective of the tense of the verb.

This means that both the past imperfect and the present perfect will be more impaired than the present imperfect.

A second goal of the current study is to compare the performance and error patterns of agrammatic and fluent speaking aphasic individuals on time reference, using the same test as Bastiaanse et al. (2011), Abuom and Bastiaanse (2013) and Dragoy and Bastiaanse (2013) did in other languages. Comparing these two groups can illuminate similarities and differences in the origin of problems with verbs that people with agrammatic and fluent aphasia have demonstrated in experiments and in spontaneous speech. Bastiaanse (2011) argued that the poor production of finite verbs in fluent aphasia is caused by the interaction of grammatical encoding and lexical retrieval. For reference to the past, discourse-linking is needed. Since discourse-linking requires additional grammatical encoding, more errors will be produced when verb forms referring to the past have to be produced. Therefore, it is predicted that

2. fluent aphasic speakers will have more problems with verb forms that refer to the past than with verb forms that refer to the non-past.

This means that it is expected that despite the different underlying disorders, the same problems will arise in agrammatic and fluent aphasia. This may show up in different error patterns.

3.2 Materials and methods

3.2.1 Participants

The participants of this study were divided into three groups: 20 NBDs, 14 individuals suffering from Broca's aphasia with non-fluent agrammatic speech

(B1 to B14) and 16 individuals suffering from fluent aphasia (Wernicke's aphasia or anomic aphasia; F1 to F16).[8] The diagnosis of the aphasic participants was done by the use of the ALLOC scores of the Dutch version of the Aachen Aphasia Test (AAT: Graetz, De Bleser, & Willmes, 1992) or the experimental Dutch version of the Comprehensive Aphasia Test (Swinburn, Porter & Howard, 2004; Dutch version: Visch-Brink, Vandenborre, de Smet, Mariën, 2014) and by clinical judgment. The experimenter elicited spontaneous speech using the methods of the AAT. Two independent judges listened to spontaneous speech samples of the participants and classified the speech as either agrammatic (telegraphic, slow speech rate, with omission of grammatical morphemes and function words) or fluent (normal speech rate, with word finding difficulties and occasional (verbal and phonemic) paraphasias and neologisms).[9] The number of words per minute was calculated over 2 minutes of spontaneous speech as an estimate of speech fluency. The auditory word comprehension test of the Boston Diagnostic Aphasia Examination (BDAE; Goodglass & Kaplan, 1972; Goodglass, Kaplan, & Baresi, 2001) served as a rough estimate of auditory comprehension (see Appendix B.1). A further 13 participants were excluded: eight because their non-fluent speech could not be classified as agrammatic, one because the independent judges did not agree on the classification of the speech, and four because they could not do the production test.

All brain-damaged participants were aphasic due to a single left-hemisphere stroke except for F6, who had a right-hemisphere stroke, F8 who had aphasia due to multiple transient ischemic attacks (TIA's), and F11 who had aphasia due to the dissection of a temporoparietal abscess. The lesion of B3 had a small right-hemisphere component. All participants were right-handed except for B12, who was left-handed. Since his performance pattern did not deviate from that of the rest of the group, it was decided to include his data in the analyses on the basis of his language profile.

All participants had normal or corrected to normal vision, and no hearing problems. Dutch was their first language, with or without a regional accent.[10] Mean age was 55.6 among the agrammatic speakers (range: 39-78) and 59.5 years (range 37-83) among the fluent speakers. In Appendix B.1, the individ-

[8]None of the participants took part in the study by Bastiaanse (2008) or Jonkers and De Bruin (2009).

[9]The spontaneous speech data will be reported in a separate paper.

[10]B10's first language has been Dutch since age 12, before that she spoke German. F9 was bilingual French-Dutch from early age onwards: He had French parents but grew up in Flanders, where Dutch is the first language.

ual characteristics are given. Twenty NBDs (10 female) were selected to match the aphasic group's characteristics. Their mean age was 54.9 year (range 40-62). As in the two aphasic groups, the educational background varied in level between high school and university. They reported no diagnosed neurological impairment or psychiatric disorder. All participants signed an informed consent according to the Declaration of Helsinki under a procedure approved by the Medical Ethics Committee of the University Medical Center of Groningen (UMCG).

3.2.2 Materials and procedure

The participants were tested with the Dutch version of the production TART (Bastiaanse et al., 2008). This test has 10 pairs of 2 semantically related transitive verbs, which were both used as target and prompt (i.e., 20 items per condition, see Appendix B.2). The verb pairs each had the same direct object, for example, *to peel/to eat an apple*. One pair appeared in each of the practice items.[11] Each verb had to be produced once per condition,[12] resulting in 54 experimental items in total (18 items times three conditions). The three tested conditions were:

Reference to non-past: simple present

→ object plus finite $\text{verb}_{\text{present tense}}$ (present tense, imperfect aspect);

(...) *een brief schrijft* (lit. 'a letter writes')

Reference to past: simple past

→ object plus finite $\text{verb}_{\text{past tense}}$ (past tense, imperfect aspect);

(...) *een brief schreef* (lit. 'a letter wrote')

Reference to past: periphrastic past

→ object plus [$\text{AUX}_{\text{present tense}}$ + participle] (present tense, perfect aspect)

(...) *een brief heeft geschreven* (lit. 'a letter has written')

[11] Eleven experimental verbs were regular (weak), and the practice items and seven experimental verbs were irregular (strong). Irregular (strong) verbs usually have a vowel change in the simple past; the participle is formed by the prefix *ge-*, followed by the stem with vowel change, followed by the suffix *–en*. The verbs were not controlled for factors such as regularity and frequency, because the pictures of the TART are used in a wide range of languages. The difference between regular and irregular verbs is not in the scope of the current work, but is under debate (e.g., Faroqi-Shah, 2007; Marusch, von der Malsburg, Bastiaanse, & Burchert, 2012; Penke & Westermann, 2006). For the sake of completeness, differential performance on regular and irregular verbs will be mentioned in a footnote.

[12] Two other conditions were tested ([modal + infinitive] and [inchoative + infinitive]). The total number of items on the test was 90. These constructions are irrelevant for the current research questions and are therefore ignored.

To create an obligatory context for time reference of the verb, a temporal adverb was added to both the probe and the target sentence, which was *nu*: 'now' for the simple non-past, *zonet*: 'a-moment-ago' for the simple past, and *net*: 'just' for the periphrastic past. The verbs were elicited in an embedded sentence, because this contains the base word order in Dutch. It has repeatedly been shown that for Dutch agrammatic aphasic speakers sentences in the base order are easier to produce than sentences in derived order (Bastiaanse, Hugen, Kos, & van Zonneveld, 2002; Bastiaanse & Thompson, 2003; Bastiaanse & van Zonneveld, 1998).

Two coloured photos above which the corresponding infinitives of the verbs were written accompanied each item. For each verb there were 2 pictures available: one depicting the completed action (past), one with the action being performed (present). In Figure 3.1 an example of a test item is provided.

The experiment started with a practice trial for each condition with the verb pair *schrijven*: 'to write' and *lezen*: 'to read'. The practice items were repeated until it was clear that the participant understood the task.

Examiner: *Hier zijn twee foto's. Dit is 'schrijven' en dit is 'lezen'. Hier kunt u zeggen 'Dit is de man die net een brief heeft geschreven' en hier kunt u zeggen 'Dit is de man die net... '*

Here are two pictures. They show the actions 'to write' and 'to read'. For this one (examiner points to the photo on the left), I could say, 'This is the man who just has written a letter'; for this picture (examiner points to the target photo on the right) you could say 'This is the man who just ... '

Participant: *een brief heeft gelezen*:

lit.'... a letter has read' ('has read a letter')

Participants were tested with the production section of the TART in a single session with a break in the middle of it. Administering the TART took approximately one hour for agrammatic speakers and 40 minutes for fluent speakers. In order to minimize fatigue effects, participants were given a break halfway during a testing session and upon request.

Figure 3.1: Example items for the Dutch TART – Production. The Dutch infinitives *lezen*: 'to read' and *schrijven*: 'to write' are written above the respective pictures. At the top: an example for the condition referring to the present. Below: an example for the conditions referring to the past. For the elicitation procedure, see text.

3.2.3 Data analysis

A correct – incorrect scoring system was used. Correct responses included the target time reference inflection on the target lexical verb. Self-corrections were counted as correct. Errors were categorised into one of four main categories: (1) non-past, (2) past, (3) infinitive or (4) uninterpretable time reference. The category non-past had subcategories for (a) periphrastic future (b) simple present; (c) semantic paraphasias ; and (d) other non-past constructions. The category 'past' had subcategories for (a) periphrastic past; (b) bare participles; (c) simple past; (d) semantic paraphasias;[13] and (e) other past constructions.[14] The fourth 'uninterpretable time reference' category included (a) utterances that were broken off before the lexical verb stem or auxiliary was realised; (b) literal repetitions of the example verb; (c) no responses; and (d) responses without a verb. Omissions or substitutions of the object were not counted as errors.

To test for an overall reliable difference between NBDs and the two aphasic speaker groups, a linear mixed-effects regression analysis was carried out using the *lmer* function of the *lme4* package (Bates, Maechler, & Bolker, 2013) and the *glht* function of the *multcomp* package (Hothorn, Bretz, Westfall, Heiberger, & Schuetzenmeister, 2013) in R (R Core Team, 2013). The dependant variable of the model was accuracy (1 = correct, 0 = incorrect) with random effect factors for participants and items. A separate model was developed to investigate differences between conditions and aphasic participant groups. This model contained the fixed effects Aphasia type, Condition and Trial number and random effect factors for Participants and Items with random slopes for Condition per Participant. The model was developed by excluding insignificant parameters from a maximal model containing the fixed effects Aphasia type, Condition, and Trial number with interactions between them. Model comparison was based on AIC and log-likelihood ratio tests (significance defined as $p < .05$). Per condition, a time reference error analysis was carried out using chi-square tests with Yates' correction for continuity to investigate the relation between aphasia type (agrammatic/fluent) and the main categories of time reference substitutions (non-past/past).

3.3 Results

In Figure 3.2, the mean percentage of correct responses on the TART-production is given for the three groups.[15] The 20 NBDs scored at ceiling. No errors were made on the simple present. Mean score on simple past was 98.9% (range

[13]Both the categories 'non-past' and 'past' had the subcategory 'semantic paraphasia', which included semantic paraphasias with the target verb inflection. Semantic paraphasias with non-target verb inflection were categorised according to the erroneous inflection, since the primary interest of the current study was time reference.

[14]Other past constructions included regular inflection on irregular verb stem, irregular inflections on regular verb stems, incompletely realised participles containing the lexical stem, and the past perfect.

[15]Adding the object sentence-final (not counted as an error) was done four times by F6, and 41 times by B9, similarly divided over the conditions.

89-100%). On periphrastic past, the mean was 99.7% (range: 94-100%). The accuracy of the agrammatic and fluent aphasic speakers was significantly lower than the accuracy of the NBDs ($\beta = 6.95$, $SE = 0.76$, $z = 9.09$ and $\beta = 5.09$, $SE = 0.75$, $z = 6.75$, respectively). The data of NBDs will be further ignored. The fluent speakers performed overall better at the test than the agrammatic speakers ($\beta = 1.86$, $SE = 0.52$, $z = 3.58$). An overview of the error type per-

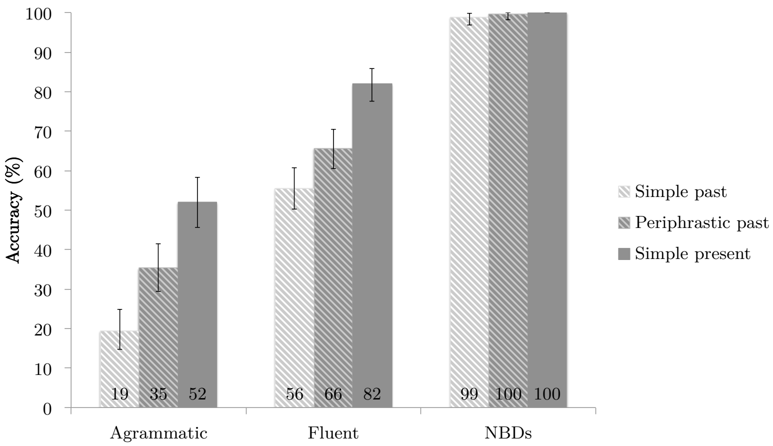

Figure 3.2: Accuracy on the verb forms per participant group, with the 95% confidence interval.

centages in each condition by the two groups of aphasic participants is given in Table 3.1. Individual accuracy scores are in Appendix B.3. There were no significant interactions between the factors Aphasia type and Condition (model with versus model without an interaction: $\chi^2\,(2) = .08$, $p = .96$). Overall, the aphasic individuals were less accurate on simple and periphrastic past than on the simple present ($\beta = 2.15$, $SE = 0.28$, $z = 7.59$ and $\beta = 1.23$, $SE = 0.40$, $z = 3.12$ respectively). Furthermore, there was a marginally significant difference between the simple past condition and the periphrastic past condition ($\beta = 0.92$, $SE = 0.40$, $z = 2.29$, $p = .06$).[16] Agrammatic speakers used an infinitive – which does not carry time reference information – for 32% of the errors

[16] Accuracy on regular and irregular verbs, respectively for agrammatic speakers: 7%-27% on simple past; 27%-41% on periphrastic past: 54%-51%, on simple present. For fluent aphasic speakers: 46%-62% on simple past; 71%-63% on periphrastic past; 83%-81% on simple present.

Target form →		Simple past		Periphrastic past		Simple present	
Substitution ↓		Agrammatic	Fluent	Agrammatic	Fluent	Agrammatic	Fluent
Non-past	Periphrastic future	5%	8%	2%	9%	18%	29%
	Simple present	18%	16%	10%	12%	-	-
	Semantic paraphasia	-	-	-	-	2%	8%
	Other non-past	9%	8%	9%	19%	9%	29%
	Total (number)	*32% (65)*	*32% (41)*	*21% (35)*	*40% (40)*	*30% (36)*	*65% (34)*
Past	Periphrastic past	20%	29%	-	-	10%	10%
	Participle	7%	13%	17%	16%	4%	2%
	Simple past	-	-	5%	24%	6%	13%
	Semantic paraphasia	1%	4%	4%	5%	-	-
	Other past	5%	14%	14%	11%	1%	2%
	Total	*33% (68)*	*60% (77)*	*40% (65)*	*57% (56)*	*21% (25)*	*27% (14)*
Infinitive		32%	6%	32%	2%	45%	4%
Uninterpretable time reference		2%	2%	7%	1%	4%	4%
Total number of errors		*203*	*128*	*163*	*99*	*121*	*52*

Table 3.1: Error types (percentages of the total number of errors) of agrammatic and fluent speakers. In grey shading are the substitution errors that have the targeted time reference.

on both the past conditions and 45% of the errors on the present time reference condition.

Analysis of the errors' time reference in the simple present condition shows that the errors had the targeted non-past time reference (χ^2 (1, N = 109) = 1.16, $p = .28$). The error patterns of the two aphasic groups differ in the simple past condition, the most difficult condition for both groups. In this condition, 33% of the errors of agrammatic speakers has past reference, compared to 60% of the errors of fluent aphasic speakers (χ^2 (1, $N = 251$) = 4.55, $p < .05$). For agrammatic speakers, substitutions of the simple past by the periphrastic past form occurred as often as substitutions by the simple present (20% and 18%, respectively). Fluent aphasic speakers substituted the simple past by the periphrastic past most frequently, in 29% of the errors. Past participles without an auxiliary and the simple present were also produced.

In the periphrastic past condition, the pattern of time reference substitutions by the two aphasic participant groups did not differ (χ^2 (1, $N = 196$) = 0.66, $p = .42$). For agrammatic speakers, errors most often constituted omissions of the tensed auxiliary (resulting in a bare participle). Agrammatic speakers applied the correct past time reference for less than half of the errors, whereas fluent aphasic speakers maintained past time reference for the majority of the errors. Most of the errors on periphrastic past by fluent aphasic speakers were substitutions by simple past or a bare participle.

3.4 Discussion

The current study aimed at investigating whether the problems with verbs referring to the past that aphasic individuals experience are restricted to the past tense or extend to past time reference in general. Second, it further investigated differences in the nature of the past time reference deficit between agrammatic and fluent aphasic speakers.

3.4.1 Past time reference deficit irrespective of tense in agrammatic aphasia

The first prediction, that in agrammatic aphasia reference to the past is impaired irrespective of the finite verb's tense, is supported by the data: Past time reference through both the simple and periphrastic past is more impaired in Dutch agrammatic speakers than the simple present. This is in line with findings from previous studies in other languages (Abuom & Bastiaanse, 2012, 2013; Abuom et al., 2011; Bastiaanse, 2008; Bastiaanse et al., 2011; Dragoy & Bastiaanse, 2013, Faroqi-Shah & Dickey, 2009; Jonkers & de Bruin, 2009; Lee et al., 2008; Nanousi et al., 2006; Simonsen & Lind, 2002; Stavrakaki & Kouvava, 2003; Wieczorek et al., 2011; Yarbay Duman & Bastiaanse, 2009) but some studies do not show a difference between past and non-past (Burchert et al., 2005; Clahsen & Ali, 2009; Kok et al., 2007; grammaticality judgment in Nanousi et al., 2006; Wenzlaff & Clahsen, 2004). The results provide further support for the PADILIH (Bastiaanse et al., 2011) that says that in order to produce a verb form that refers to the past, a link has to be made in discourse, for which discourse syntax is needed. This process is, however, compromised in agrammatic aphasia (Avrutin, 2000, 2006). The PADILIH does not apply to tense, but to the time reference of the verb form as a whole. Time reference assignment to a verb is an interaction between tense, aspect and context. The deficit is, thus, independent of whether the past time reference is expressed through past or present tense: The periphrastic past form, with an auxiliary in present tense, was also impaired compared to the simple present.[17]

3.4.2 Time reference in agrammatic and fluent aphasia

The second prediction was that fluent aphasic speakers also encounter more problems with verb forms referring to the past than with verbs referring to the non-past, even though they suffer from a different underlying deficit. The data also supported this hypothesis. However, the agrammatic speakers were overall less accurate than the fluent aphasic speakers. Of course, the overall degree of the time reference difficulties may have been influenced by the severity of aphasia in the two groups. The Dutch agrammatic speakers perform more poorly in the present tense condition than the English (78% correct) and Turkish (72% correct) agrammatic speakers of Bastiaanse et al. (2011), although the test was the same. What is important, however, is that the pattern of impairment is the same in agrammatic and fluent aphasia: There was no interaction between the factor of aphasia type and the factor of condition (see also Figure 1). For the aphasic individuals overall, time reference to the past was more impaired than time reference to the present. Also in the healthy language system, discourse-related differences between non-past and past time reference exist (Dragoy, Stowe, Bos, & Bastiaanse, 2012) which are irrespective of tense, as shown in neurophysiological responses to time reference violations (Bos et al., 2013).

The production accuracies on the simple present condition were not at ceiling, either. The PADILIH does not suggest that that tense as such is unaffected in aphasia, but that past time reference is particularly difficult compared to non-past time reference. Other studies have addressed a general difficulty with tense in agrammatism (e.g., Burchert et al., 2005; Clahsen & Ali, 2009; Faroqi-Shah & Dickey, 2009; Friedmann & Grodzinsky, 1997; Kok et al., 2006; Nanousi et al., 2006; Wenzlaff & Clahsen, 2004, 2005).

The difference between agrammatic and fluent aphasia becomes apparent by an error analysis. Both groups made errors in all conditions, but in the two past conditions, fluent aphasic speakers' errors generally referred to the past, while the majority of agrammatic speakers' errors did not. In the most

[17]However the simple past appears around twice as often as the present perfect in the Spoken Dutch Corpus (2009), agrammatic speakers may sometimes exhibit a preference for verb forms that have a lower frequency of occurrence than other verb forms (Bastiaanse, Bouma, & Post, 2009).

difficult condition, the simple past, fluent aphasic speakers frequently used the periphrastic past. In the majority of cases, agrammatic speakers produced verb forms without past time reference (infinitives and simple present forms), but if they remained in the correct time frame, they preferred the use of periphrastic past to the use of simple past as well.

The results are in line with the data of the Russian agrammatic speakers tested by Dragoy and Bastiaanse (2013). The agrammatic speakers assigned temporal relations in a less consistent way than the fluent aphasic speakers. Agrammatic speakers of both Dutch and Russian produced more infinitives and other forms without time reference than the fluent aphasic speakers did. However, in Russian, not only agrammatic, but also fluent aphasic speakers changed the target past time reference to non-past time reference in most cases. This difference is probably related to structural differences between the two languages. Aspect in Russian is lexicalized, meaning that perfect and imperfect verbs are separate lexical entries. When making errors, the Russian aphasic speakers usually retained the target aspect and, therewith, the target lexical verb, but consequently not the target time reference. In Dutch, aspect is less prominent and fluent aphasic speakers generally produced errors with the target past time reference.

3.4.3 Same patterns, different underlying disorders

Discourse-linking poses difficulties for both fluent and agrammatic aphasic speakers, but the underlying disorder is different in these two groups. Agrammatic speakers have problems with grammatical encoding. The more grammatical encoding is required, that is, the more grammatical operations are needed, the more problems arise for agrammatic individuals (see, e.g., Bastiaanse & van Zonneveld, 2004). Reference to the past requires discourse-linking (Zagona, 2003) and discourse-linking requires additional resources at the level of grammatical encoding (Avrutin, 2000, 2006). Agrammatic speakers avoid this discourse-linked processing by not referring to the past: The majority of their errors are non-past verb forms. Fluent aphasic speakers have problems with lexical retrieval. If more resources are needed for grammatical encoding — which is the case when discourse syntax is required — lexical retrieval will diminish. As a result, they experience difficulties in retrieving the correct lexical form. Discourse-linking requires extra grammatical encoding. Since neither of these processes as such is impaired, the verb forms that are produced are still in the correct time frame. However, the correct verb form is no longer retrieved when additionally extra grammatical encoding is needed: Simple and periphrastic forms are replaced by each other.

In conclusion, agrammatic and fluent aphasic speakers suffer from different underlying deficits. However, complex grammatical operations influence performance in both aphasia types. The current study focused on time reference and showed that reference to the past through verb inflection is more difficult than reference to the non-past for both aphasia types. This is explained by the need of discourse-linking in case of verb forms referring to the past. When grammatical encoding is affected, as is the case in agrammatic aphasia, problems with discourse-linking arise and verb forms referring to the past are being replaced by verb forms referring to the non-past. When lexical retrieval is impaired, extra grammatical encoding, as needed for discourse-linking, diminishes lexical retrieval and verbs forms referring to the past are confused.

CHAPTER 4

Time reference teased apart from tense in the healthy brain[1]

Abstract — Reference to a time frame in which an event takes place can be done by verb inflection. If the time frame (past, present, future) is set by a temporal adverb, the verb inflection should correspond ('yesterday he walk*ed*'; 'today he walk*s*'). Temporal violations by simple verbs (single, lexical verbs inflected with tense) in the present tense and with present time reference elicit a P600 effect (Baggio, 2008; Dragoy, Stowe, Bos, & Bastiaanse, 2012). 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 current study investigates whether the P600 effects described by Dragoy et al. and Baggio are 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 show that the P600 effect for violations of the

[1]This chapter was adapted from: Bos, L.S., Dragoy, O., Stowe, L.A. & Bastiaanse, R. (2013). Time reference teased apart from tense: Thinking beyond the present. *Journal of Neurolinguistics, 2*, 283-297.

temporal context is caused by the time reference of the complete verb form, rather than by the tense.

4.1 Introduction

The use of verb morphology to express temporal relations has been widely studied in linguistics. Languages such as English and Dutch use verb inflections for both tense and aspect. *Tense* provides information about *when* an event happens/happened. More precisely, it contains information about the temporal relation, such as 'simultaneity' or 'precedence,' between the time interval of the event expressed through the verb morphology and the time of evaluation set by the context. The evaluation time can be, for example, the speech time (the time of the speaker's context) or the time of the matrix clause event. *Aspect* further specifies temporal relations by providing information about the boundaries (beginning, end point) of a situation. It tells the listener whether the event is seen as completed or as ongoing (Comrie, 1976). There is a clear distinction between tense and time reference, both of which are characteristics of temporal relations. *Tense* is a morphological element within a finite (i.e., tense-inflected) verb, while *time reference* is a semantic feature of the event being described and is a characteristic of a verb complex as a whole. It is the combination of tense, aspect and context that specifies the time reference. The difference between tense and time reference becomes clearest when present tense is used in a construction that refers to the past, which is possible in Dutch, for example. This will be further elaborated in the current study.

The outline is as follows: In the introduction, more theoretical background on time reference will be provided. Then, findings from aphasia will be discussed that demonstrate that for agrammatic speakers reference to the past is selectively impaired. In agrammatic aphasia, the time reference deficit is irrespective of tense, because past time reference by a construction containing a present tense auxiliary is also impaired. The distinction between past and present seems also to exist for non-brain-damaged adults. An ERP study by Dragoy, Stowe, Bastiaanse and Bos (2012) in healthy individuals showed differential responses to present and past time reference violations. This study does not reveal whether the differential neural responses for past vs. non-past reported in Dragoy et al. (2012) are due to tense morphology per se or to time reference. The aphasiological data would predict the latter. The goal of the current experiment is to investigate whether it is in fact tense or time reference which evoked the ERP effects in Dragoy et al. (2012).

4.1.1 Theoretical background on time reference and discourse-linking

Tense and aspect can be expressed on a single lexical verb, called a 'simple verb form,' for example *writes.* If the verb form consists of an auxiliary plus a lexical verb, it is called a 'periphrastic verb form,' for example *has written* or *will write*, as illustrated in the Dutch sentences in (1) and (2). *Heeft*: 'has' and *gaat*: 'will' are both inflected for tense and agreement and are called temporal auxiliaries, because they are used for time reference.

(1) *De man*	*heeft*	*de brief*	*geschreven.*
the man	$\text{has}_{\text{present tense}}$	the letter	$\text{written}_{\text{past participle}}$
'The man has written the letter.'			
(2) *De man*	*gaat*	*de brief*	*schrijven.*
the man	$\text{will}_{\text{present tense}}$	the letter	$\text{write}_{\text{infinitive}}$
'The man will write the letter.'			

Note that the Dutch construction [have + participle] refers to past time much more generally than the present perfect of English, which focuses on completion before the evaluation time (the moment of speaking).[2]

These examples show that present tense can be decoupled from present time reference, since it can refer to different time frames depending on whether it occurs on a simple or periphrastic verb form, and on which periphrastic verb form it occurs. In (1), the present tense of the auxiliary *heeft*: 'has' is used in combination with the participle *geschreven*: 'written' to refer to a point prior to the evaluation time. In (2), the auxiliary in present tense *gaat*: 'will,' when combined with an infinitive, refers to the non-past (i.e., the future). In examples (1) and (2), at *heeft*: 'has' and *gaat*: 'will,' the listener may already interpret the time reference of the periphrastic verb form, even though the past participle or infinitive has not yet been encountered. This system of periphrastic verb forms creates a paradox in which a verb in present tense can be used to refer to the past, as in (1), as well as to the non-past (here future), as in (2).

In order to interpret the verb tense more than superficially, it is necessary to

[2] The meaning of the Dutch present perfect is closer to the English simple past than to the English present perfect, but to indicate that it is a periphrastic verb form, throughout this article the literal translation (e.g. 'has written') will be used.

refer to the time specified in the discourse context. Tense is therefore considered to be anaphoric in nature, in the sense that it is used to refer to a more specific time frame which is set by the previous context (Reichenbach, 1947; Partee, 1973; Aronson, 1977; Enç, 1987). Therefore, it has been suggested that tense is 'discourse-linked,' or in terms of Avrutin (2006), processed by 'discourse syntax.' Zagona (2003), however, points out that the present tense is less dependent on discourse context than the past. According to her, in present tense the moment of speaking and the event coincide. That is, present tense is locally 'bound' to the moment of speaking rather than being linked to discourse. Only the past tense needs to be discourse-linked.

In line with Aronson (1977) and Partee (1973), Zagona (2013) proposes that future tense should be seen as a form derived from the present tense via modal and aspectual features and is, therefore, a sub-class of present tense. This view is adopted here, and only a distinction between past and non-past time reference will be made. It is assumed that reference to the past is discourse-linked and reference to the non-past is not.

4.1.2 Neuro- and psycholinguistic background

The research question of the current experiment has its roots in aphasiology. Tense inflection is problematic for people with aphasia (Faroqi-Shah & Thompson, 2007; Friedmann & Grodzinsky, 1997; Wenzlaff & Clahsen, 2004). According to Bastiaanse (2008; Bastiaanse et al., 2011), however, the idea that tense is what is impaired is both too narrow and too broad. The view is too narrow, because the problems are not restricted to tensed verbs, but extend to periphrastic verb forms. It is too broad because the deficit is highly selective: Verb forms referring to the past are impaired, whereas verb forms referring to non-past are relatively spared. Based on an extensive review of aphasiological production and comprehension data, Bastiaanse et al. (2011) formulated the PAst DIscourse LInking Hypothesis (PADILIH) to describe the pattern of relatively spared time reference to the present in production and comprehension. The PADILIH claims that reference to the past is discourse-linked, regardless of the anaphoric means employed (i.e., not only through tense as suggested by Zagona, 2003). This explains the problems specific to the past found in individuals with agrammatic aphasia since discourse-linking is impaired in agrammatic aphasia (see Avrutin, 2000, 2006). Therefore, reference to the past through any form of grammatical morphology, including simple past tense verbs, perfect aspect, periphrastic verb forms and perfective aspectual adverbs (used for time reference in many East Asian languages), are difficult in agrammatic aphasia.

Behavioral evidence from healthy processing

One of the issues in neurolinguistic research is to what extent the language problems of aphasic individuals are related to linguistic complexity. Possibly, the constructions that are vulnerable in aphasia are also associated with greater memory load or processing difficulty for the healthy brain. It is therefore of importance to investigate in what way the healthy brain processes time reference. In non-brain-damaged people (discourse-related) differences in the processing of past and non-past time reference have also been found (Dragoy et al., 2012; Faroqi-Shah & Dickey, 2009), which suggests that the PADILIH applies to the normal language system, as well as to the language system after brain damage. Faroqi-Shah and Dickey (2009) gave agrammatic aphasic speakers and healthy control participants a grammaticality judgment task with tense violations. Their materials included sentences with tense violations on simple verbs of the following type: *Last year, my sister *lives in Boston*, violations by present tense auxiliaries such as: *Yesterday, the honors student *will know an answer*, and violations by past tense auxiliaries as in: *Next year, my younger step-sister *did not live in Boston.* Healthy participants and agrammatic individuals found it easier (reflected in shorter reaction times) to detect violations of past context by present tense verbs than violation of non-past context by past tense verbs. Additionally, reaction times were shorter when the past or non-past tense was marked on the auxiliary (the first part of a periphrastic verb form) than when it was marked on a simple verb (a single lexical verb form), although accuracy did not differ in these conditions.

ERP studies on time reference

ERP studies that have used verb violations focused on morphological processing rather than time reference per se (see Dragoy et al., 2012, for a summary). There are two ERP studies that use true time reference violations, one by Baggio (2008) and one by Dragoy et al. (2012), both on Dutch.[3] Baggio (2008) used visually presented sentences in Dutch in which a temporal context was set by an adverbial phrase that was violated by a verb in present tense, such as: *Afgelopen lente *wint/won Julian een literatuurprijs in Frankrijk*: 'Last spring Julian *wins/won a prize in literature in France.' He found brain responses typically evoked by morphosyntactic mismatches: a left anterior negativity (LAN), associated with detection of morphosyntactic and word form violations (Neville, Nicol, Barss, Forster, & Garrett, 1991). Additionally he reported a P600, which, among other syntactic violations (Osterhout & Holcomb, 1992), is elicited by violations of a morphosyntactic relation involving locally bound pronouns (Harris, Wexler, & Holcomb; Osterhout & Mobley, 1995; for more background, see Dragoy et al., 2012). This is in line with the claim that processing present time reference, like processing locally bound pronouns, does not involve discourse-linking. The P600 is generally argued to be a marker of sentence reanalysis and repair (Friederici, Hahne, & Saddy, 2002; Hagoort, 2003a; Kaan & Swaab, 2003; Osterhout, Holcomb & Swinney, 1994) but has recently also been linked to integration of lexical information with the contextual semantic representation (Brouwer, Fitz, & Hoeks, 2012; Kuperberg, Sitnikova, Caplan, & Holcomb, 2003). Furthermore, Baggio found a broadly distributed negativity between 400 and 700 ms after the final word of the sentence, which he attributed to the brain's attempts to compute a meaningful sentence.

However, Baggio (2008) showed the effects of violation of time reference only for (locally bound) present tense verbs in a past context. Violations by past tense verbs are predicted to be processed differently under the PADILIH, since they are discourse-linked rather than locally bound. A direct comparison between these two cases was made by Dragoy et al. (2012). Examples of the sentences are given in (3) and (4), with the critical verbs in bold (critical clause in square brackets, with the second adverb inducing a time reference violation by the verb).

[3]In a study by Fonteneau, Frauenfelder, and Rizzi (1998), time reference violations of a past context by a future verb were used. However, these authors used a different ERP measurement paradigm, namely average referencing (p.c.). The preliminary effects (a frontal positivity and posterior negativity between approximately 450 and 550 ms) found in this study can, therefore, not be claimed to be the same as or different in scalp distribution from standard ERP effects such as the P600 and LAN, making the study hard to interpret (see Luck, 2005 for more background on this topic).

(3) *De kelner*	*[die nu/zonet*	*de peper*	*maalt]*	*krijgt geen fooi.*
the waiter	[who now/a-moment-ago	the pepper	grinds]	gets no tip
'The waiter who is now/a-moment-ago grinding the pepper doesn't get a tip.'				
(4) *De kelner*	*[die zonet/nu*	*de peper*	*maalde]*	*krijgt geen fooi.*
the waiter	[who a-moment-ago/now	the pepper	ground]	gets no tip
'The waiter who a-moment-ago/now has ground the pepper doesn't get a tip.				

Participants showed a P600 effect time-locked to the critical verb in present tense, replicating Baggio's (2008) results, but no ERP effect occurred time-locked to the critical verb in the past tense, supporting the hypothesized dissociation between past and present time reference. At the end of the sentence, a negativity occurred for both sentence types. Sentence final negativity has been reported following violation of morphological errors earlier in the sentences, both due to local binding and discourse-linking (Harris et al., 2000; Osterhout & Mobley, 1995) and has been interpreted as being related to memory load or processing difficulty. Dragoy et al. (2012) used the same sentences in an on-line grammaticality judgment task. The participants were less accurate and slower in detecting the temporal violations by verbs in past tense with past time reference than by those in present tense with present time reference. In a binary off-line acceptability rating of a) fragments ending at the embedded tensed verb, and b) of the complete sentences, both violated sentence types were judged as incorrect. Taken together with the ERP results, this means that time reference violations by verbs in present tense with present time reference and past tense with past time reference are both detected but they are processed differently on-line. Dragoy et al. (2012) suggested that these different processing patterns are in line with the PADILIH: when a verb form referring to the past is detected, processing load increases, leading to different neural responses because a discourse link has to be made. Non-past time reference does not require this link and temporal violations by a present tense verb evokes an immediate ERP effect and a quicker behavioral response.

4.1.3 The current study

The ERP studies performed by Baggio (2008) and Dragoy et al. (2012) showed that in a context of past time reference, a violation by a present tense simple verb causes a P600 effect when compared to correct sentences. Bastiaanse (2008) and Bos, Brederoo, and Bastiaanse (2011) showed that for agrammatic speakers, periphrastic verb forms with a present tense temporal auxiliary ('has V-ed') are equally difficult as past tense verbs ('V-ed'): both forms (that refer to the past) are harder to produce than simple present tense verbs (that refer to the present). The time reference difficulties that people with aphasia experience are thus irrespective of tense. These findings are consistent with the PADILIH. The aphasiological data suggest that the positive ERP component that was found on the present tense verbs of the Dragoy et al. (2012) study was caused by a disruption of local binding of time reference expressed by the verb form rather than its tense. In the current study, we aim to find support for this hypothesis by testing violations with periphrastic verb forms, so that tense and time reference can be teased apart. We formulated two predictions based on past results and the PADILIH. Examples of the contrasting sentences are given in Table 4.1.

1. If local binding occurs for present time reference as claimed in the PADILIH, rather than for present tense, we predict that violation of a past time context with a non-past periphrastic verb form elicits a P600 time-locked to the auxiliary, relative to a congruent past periphrastic verb form. This is predicted to be true although the auxiliaries in the two constructions do not differ in tense.

2. Based on the findings of Baggio (2008) and Dragoy et al. (2012) we predict that violation of a past time context by a non-past simple verb form will elicit a P600, and that this is comparable to the response to the periphrastic verb forms.

We constructed materials with the sentence structures used by Dragoy et al. (2012), except that periphrastic rather than simple verbs were used (see example materials 3 and 4 in Table 4.1). In contrasting pairs, we kept the context (the temporal adverb) constant, as Baggio (2008) did. This allowed us to compare effects of time reference alone, decoupled from tense effects. If tense morphology but not time reference caused the P600-effect in the studies by Baggio (2008) and Dragoy et al. (2012), this ERP-effect should not appear in the comparison where tense is kept constant (1).

In the comparison between the periphrastic verb forms, two different present tense auxiliaries (‘has’ and ‘will’) were compared in past contexts. Since these two forms differ in factors such as word stem, length and frequency, we included two conditions in which both auxiliaries are consistent with the preceding temporal context to ensure that the differences in the primary comparison are due to temporal violation and not to these other factors.

4.2 Materials and methods

The materials for this study were collected within a larger scale project which generated data used for Dragoy et al. (2012) as well. Experimental conditions from that study with a simple target verb were reanalyzed for the purpose of the current study (see examples 3-4 above and 1-2 in Table 4.1), and compared to experimental conditions with a periphrastic target verb that have not been analyzed previously.

4.2.1 Participants

Forty right-handed healthy college students took part in the experiment, all native speakers of Dutch. Eight were excluded from analysis due to excessive artifacts in their EEG signal. The remaining participants (12 male, 20 female) had a mean age of 22.7 years (range 18-31). They had normal or corrected to normal vision, had never been diagnosed with speech and/or language disorders (including dyslexia), neurological impairments or psychiatric disorders, and reported no usage of alcohol, drugs or medications that could influence their performance in the experiment. They were distributed over four lists (3 male, 5 female on each list). They signed an informed consent according to the Declaration of Helsinki following a procedure that was granted approval by the Medical Ethics committee. They were paid €20 for their participation in the experiment.

4.2.2 Materials

The ERP experiment contained Dutch sentences in six experimental time reference conditions, illustrated in Table 1. The first prediction was tested by pairs which contained past (3: PeriPast-congruent) and non-past periphrastic target verbs (4: PeriNonpast-incongruent). A control for possible differences between the past and non-past periphrastic verb forms was provided by pairs containing an adverb referring to the non-past. Both the non-past and the past periphrastic construction are acceptable as to time reference and tense in these sentences (5-6: PeriNonpast control and PeriPast control). In order to test the

Table 4.1: Examples of the six experimental conditions. Note that the condition NonPast-PeriPast does not contain a violation, because the past that is being referred to by the verb is relative to the reference time of the sentence. The event time can lie in between the utterance time and the reference time.

Condition	**Tense**	**TR Adverb**	**TR Verb**	**TR violation?**	**Example**
(1) SimplePast-Congruent	past	past	past	No	*De kelner die* ***zonet*** *de peper* ***maalde*** *krijgt geen fooi.* the waiter who a-moment-ago the pepper ground gets no tip The waiter that a-moment-ago ground the pepper doesn't get a tip.
(2) SimpleNonpast-Incongruent	present	past	non-past (present/ future)	Yes	*De kelner die* ***zonet*** *de peper* ***maalt*** *krijgt geen fooi.* the waiter who a-moment-ago the pepper grinds gets no tip *The waiter that is a-moment-ago grinding the pepper doesn't get a tip.
(3) PeriPast-Congruent	present	past	past	No	*De opa die* ***zonet*** *de koffie* ***heeft gemalen*** *zorgt voor zijn bezoek.* the grandpa who a-moment-ago the coffee has ground looks after his visitors. The grandpa that a-moment-ago ground the coffee looks after his visitors.
(4) PeriNonPast-Incongruent	present	past	non-past (future)	Yes	*De opa die* ***zonet*** *de koffie* ***gaat malen*** *zorgt voor zijn bezoek.* the grandpa who a-moment-ago the coffee will grind looks after his visitors. *The grandpa that a-moment-ago will grind the coffee looks after his visitors.
(5) PeriNonPast-Control	present	non-past	non-past (future)	No	*De opa die* ***straks*** *de koffie* ***gaat malen*** *zorgt voor zijn bezoek.* the grandpa who soon the coffee will grind looks after his visitors. The grandpa that will soon grind the coffee looks after his visitors.
(6) PeriPast-Control	present	non-past	past (of future reference point)	No	*De opa die* ***straks*** *de koffie* ***heeft gemalen*** *zorgt voor zijn bezoek.* the grandpa who soon the coffee has ground looks after his visitors. The grandpa that will soon have ground the coffee looks after his visitors.

TR = Time Reference.

second prediction, pairs of sentences were contrasted which contained simple target verbs which referred to the past (1: SimplePast congruent) and non past (2: SimpleNonpast incongruent) respectively.

To provide these conditions, 160 sentence frames were constructed, each of which consisted of a main clause and a center-embedded subject relative clause in which the violation occurred.[4] The noun phrases of the experimental relative clauses were matched for animacy (the subject was animate; the direct object was generally, if semantics permitted, inanimate), concreteness (no abstract nouns occurred in the embedded relative sentence), frequency (9 or more occurrences per million in the Dutch CELEX database for written language; Baayen, Piepenbrock, & van Rijn, 1993) and length (3-10 letters).

Each of the 160 frames were used to construct sets of four sentences differing in the form of the target verb (past vs. non-past) which appeared at the end of the embedded clause and a past or non-past temporal adverb following the relative pronoun of the embedded clause to provide the time reference context. Eighty sentence frames contained simple verb forms. These are the materials of Dragoy et al. (2012); a complete description of these materials can be found there. Two conditions for the current comparison (SimplePast congruent and SimpleNonpast incongruent) come from those sets of sentences.

The remaining 80 sentence frames were used to construct quadruplets which provided the other four conditions with periphrastic verb forms described above. Two of the versions contained the present perfect *heeft*: 'has' + past participle and the other two the future periphrastic *gaat*: 'will' + infinitive. Two versions contained the past temporal adverb *zonet*, which was acceptable with the present perfect form (PeriPast-congruent), but not with the future (PeriNonpast-incongruent). The other two contained the future temporal adverb *straks*, which is acceptable with both the future periphrastic (PeriNonpast-control) and the present perfect (PeriPast-control), interpreted as completed in the future.

Although the periphrastic and simple sentence frames otherwise contained different lexical items and are entirely different sentences apart from the structure, the same eighty verbs were used in both sets. For a complete description

[4]In Dutch, the base word order is Subject–Object–Verb. In order to avoid interference with derived word order and a sen- tence-final effect, the violations were tested in center embedded clauses.

of the verb choice see Dragoy et al (2012).[5] In the conditions with periphrastic non-past, for 7 of the 80 verbs the auxiliary for future reference *zal*: 'will' was used instead of *gaat*: 'will'. Both auxiliaries are used for future reference in Dutch. Of the 80 verbs used in experimental sentences, 58 contained a transitive target verb and 22 an intransitive target verb. In sentences with an intransitive verb, an adverbial phrase was added to match in length with sentences containing a transitive verb. Intransitive verbs describing a change of state or direction of the subject take *zijn*: 'to be' instead of *hebben*: 'to have' as an auxiliary (Haeseryn, Romijn, Geerts, de Rooij, & Van den Toorn, 1997). This form – with third person singular present tense *is* instead of *heeft* – occurred twice in PeriPast-congruent and (accordingly) twice in the PeriPast-control sentences.

To avoid repetition, the 160 sentence quadruplets were divided over four lists, so that subjects say only one version. Each list contained an equal number of sentences in each condition; the participants read 20 sentences per experimental condition. Care was taken that the two sentences containing the same verb were not close to each other within the list. In sum, the participants were presented with 300 sentences, a third of them containing a violation. A subset of 120 sentences were experimental sentences of the current study.

4.2.3 Procedure

The stimuli were programmed and presented using E-prime (Psychology Software Tools Inc., 2001). Data collection took place in a dimly lit sound-proof cabin where participants sat at approximately 80 cm distance from a computer screen. In the middle of the computer screen, the sentences were presented word by word in black on a white background in 12 point font size. An asterisk marked a fixation point for 500 ms prior to the beginning the each sentence. Words were presented for 240 ms each and followed by a 240 ms blank screen. After each sentence, a row of asterisks appeared for 1750 ms, indicating the opportunity to blink. Participants received the instruction to read each sentence for comprehension and to answer occasional questions about the previous sentence. The questions were simple and randomly appeared after 25% of the

[5]The word forms *heeft*: 'has' and *gaat*: 'will' can also be used as lexical verbs rather than auxiliaries: *Hij heeft een boek*: 'He has a book' and *Hij gaat naar school*: 'He goes to school'. However, because they are frequently used as auxiliaries (log frequency of at least 2.3 in the Lassy Small corpus; van Noord et al., 2012), the auxiliary interpretation is certainly constructed here.

sentences; they were meant to check the participants' attention and comprehension. The question disappeared as soon as a response was given, or after a 10 s time out. Participants had to respond by pressing keyboard buttons '1' or '2,' which indicated 'Yes' or 'No' respectively. Each list was divided into six blocks which lasted 7 to 10 minutes each. The participants took a short break after completing a block. Testing took approximately 1 hour in total.

4.2.4 EEG recordings and data analysis

EEG was recorded from 64 electrode sites according to the extended 10-20 system using an elastic cap mounted with tin electrodes (Electro-Cap International Inc.), plus the two mastoid electrodes averaged as offline reference. A ground electrode was placed on the sternum. Bipolar EOG was measured above and below the left eye vertically and from the left and right canthus horizontally. The impedance of the electrodes was kept below 10 kΩ (mean: 2 kΩ). Offline data processing in BrainVision Analyzer (Brain Products, Munich, Germany) and followed the same procedure as Dragoy et al (2012) which is described in detail in that article (pp. 313-314). The mastoid electrodes served as reference for the averaged waveforms, a 200 ms pre-stimulus baseline was used and average waveforms were computed per person for each condition for each electrode.

The analysis included 43 electrodes divided over 15 regions of interest (ROIs), the same as reported in Dragoy et al. (2012): frontal left (AF3, F3, F7), frontal right (AF4, F4, F8), fronto-central left (FC1, FC3, FC5), fronto-central right (FC2, FC4, FC6), central left (C1, C3, C5), central right (C2, C4, C6), centro-parietal left (CP3, CP5), centro-parietal right (CP4, CP6), parietal left (P1, P3, P5), parietal right (P2, P4, P6), parietal-occipital left (PO3, PO7, O1), parietal-occipital right (PO4, PO8, O2), anterior midline (Fpz, AFz, Fz), central midline (FCz, Cz, CPz), and posterior midline (Pz, POz, Oz).

The same time windows as in Dragoy et al. (2012) were used: 300-500 ms, 500-700 ms and 700-1000 ms time-locked to the critical tensed verb (simple lexical verb or auxiliary) and 300-500 ms time-locked to the sentence-final word. Time windows were analyzed using separate repeated measures ANOVAs for midline and lateral ROIs. Factors in the ANOVAs were violation (for the control comparison PeriNonpast-control versus PeriPast-control this factor should more accurately be called the target auxiliary, since here, no violation occurred), posteriority (with 3 levels for midline analyses and 6 levels for lateral analyses) and laterality (left and right). This factor was not included for the midline analysis. For the analysis at the target verb, the factor context (past or non-past) was included for the periphrastic verb conditions. This allows us to separate effects of differences between the two periphrastic forms, which should show up for both past and non-past contexts, and effects of violation, which should only be present for the past context. If there were significant interactions which indicated an effect of violation was present, further analyses were carried out for the periphrastic and simple violation pairs. For the comparison between the effects on simple and periphrastic verbs, a 2 x 2 analysis was carried out with the factor verb type added to violation. For the sentence-final time windows, all three pairs were included into a single analysis with the three levels past + simple versus past + periphrastic versus control + periphrastic to investigate interaction effects between the response to past versus non-past in these different contexts.

In the Results section, the focus will be on main effects of violation and interactions of this factor with posteriority and/or laterality. Since scalp distribution effects that do not relate to the effects of interest are not relevant for this study, these will not be reported or discussed. Original degrees of freedom are reported and (where appropriate) the Greenhouse-Geisser corrected p-values. The significance criterion was set at $p < .05$.

4.3 Results

The mean of the participants' correct responses to randomly presented questions in this study was 96% (SD = 0.025%), which suggests that the participants read the sentences attentively. None of the participants was excluded from further analysis based on the behavioral data.

In the sentence-final time window, there were no significant effects or interactions, so these will not be presented further. Below, the results on the critical verbs of the time reference conditions are reported.[6] An illustration of the grand average ERP waveforms for correct and violation sentences with periphrastic verbs is given in Figure 4.1. A violation of a past time reference context by the auxiliary of a periphrastic verb with non-past time reference

[6] An analysis on the data with the auxiliaries *heeft* and *gaat*, leaving out 2 instances of *is* and 8 instances of *zal*, did not yield different results from the analysis reported in the body of the text

seems to evoke a large positivity with initially, from 300 ms onwards, a broad distribution over the skull. A positivity is also apparent for the simple verbs which violated the past context, which appears to start later and to be somewhat more limited to posterior electrodes (see Figure 4.2). There is no apparent difference between the two periphrastic forms in the control context where both have correct time reference (see Figure 4.3). Three time windows will be examined, based on the time windows reported by Dragoy et al. (2012).

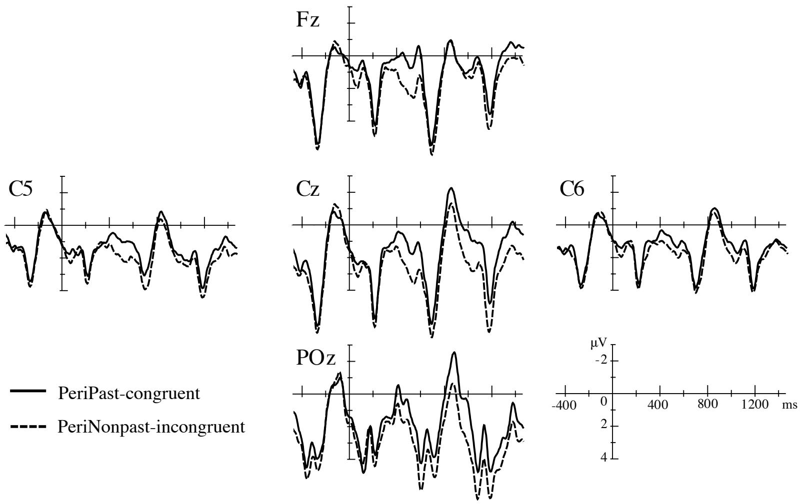

Figure 4.1: ERPs for conditions PeriPast-congruent vs. PeriNonpast-incongruent. A positivity is seen in response to a time reference violation by the auxiliary in a periphrastic verb, where there is no difference between the conditions with regard to tense. The violation evokes a broad centrally distributed positivity which appears to start around 300 ms. The effect only becomes statistically different from control sentences at around 500 ms, then continues as a more posteriorly distributed effect from around 800 ms.

4.3.1 Time window 300-500 ms

Testing the first prediction, sentences with a context of the past adverb *zonet*: 'a-moment-ago' followed by the present tense auxiliary *heeft*: 'has' (condition PeriPast-congruent) with past time reference were contrasted with sentences with the same past adverb context violated by the non-past time reference of

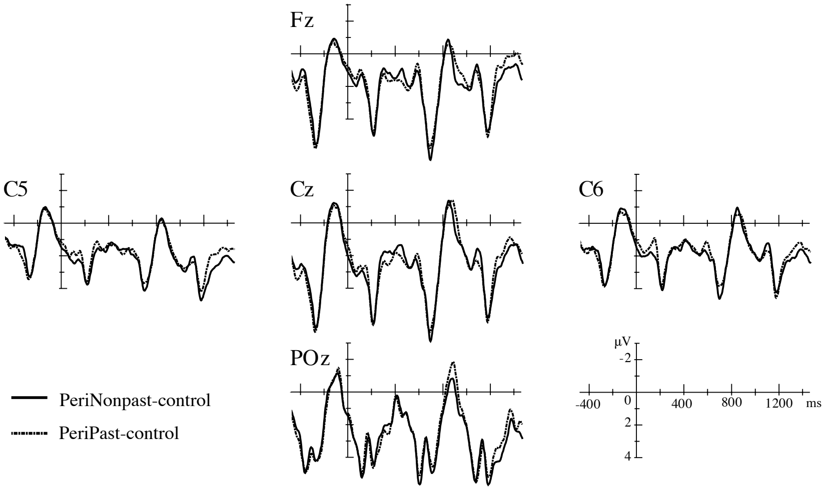

Figure 4.2: ERPs for conditions PeriPast-control vs. PeriNonpast-control. No difference is seen between past and non-past periphrastic verb forms in the control comparison in which no temporal context violation occurs.

the present tense auxiliary *gaat*: 'will' (condition PeriNonpast-incongruent). A significant main effect of violation is apparent over midline ROIs ((F (1, 31) = 6.00, $p < .05$)) and over lateral ROIs (F (1, 31) = 4.11, $p = .05$). However, this effect could simply be due to the differences between the periphrastic forms. Control conditions to examine whether this was the case consisted of sentences containing the two periphrastic verb forms following the non-past time reference adverb *straks*: 'later,' which matches both the tense and time reference of both auxiliaries. This allows comparison of the processing of the present tense verb *heeft*: 'has' (condition PeriPast-control) with the processing of the present tense verb *gaat*: 'will' (condition PeriNonpast-control), independent of violation, as illustrated in Table 4.1.

For the comparison of the effect on periphrastic verbs with the control sentences, an overall analysis was carried out including the factors past versus non-past time reference of the verb phrase (auxiliary), the two temporal adverbs, and the factors posteriority and, for the lateral analysis, laterality. The overall analysis over midline ROIs shows a significant main effect of the temporal adverb (F (1, 31) = 4.43, $p < .05$) and of the auxiliary (F (1, 31) = 6.08,

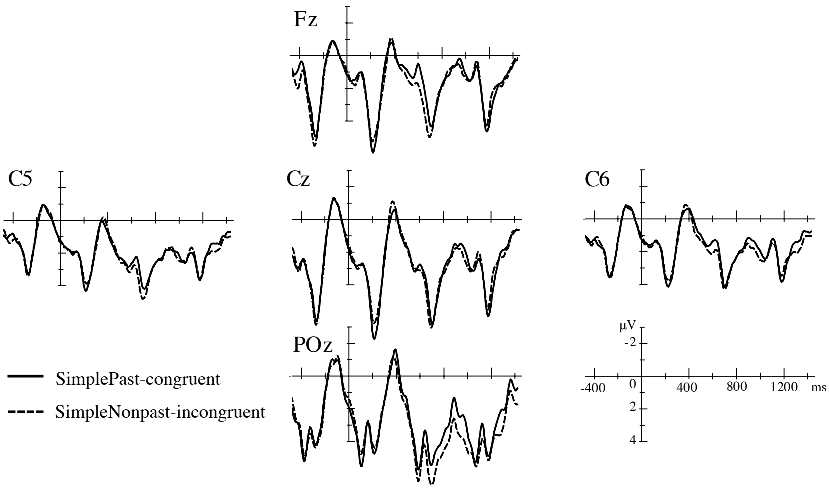

Figure 4.3: ERPs for conditions SimplePast-congruent vs. SimpleNonpast-incongruent. A positive effect is seen here in response to a time reference violation by a simple verb, for which tense and time reference cannot be distinguished. The effect starts around 600 ms and has a posterior distribution.

$p < .05$), and over lateral ROIs tendencies for main effects of the adverb (F (1, 31) = 3.38, $p = .08$) and of the auxiliary (F (1, 31) = 3.74, $p = .06$). However there was no sign of an interaction. Since the main effect cannot be attributed to the violation because no differences with the control sentences are found, this time window will not be further analyzed for the simple verbs.

4.3.2 Time window 500-700 ms

As compared to correct sentences, a past time reference violation by an auxiliary of a periphrastic verb form with non-past time reference shows a broadly distributed positive effect in this time window (see Figure 4.1). Just as for the first time window, sentences of the condition PeriPast-congruent are contrasted with sentences of the condition PeriNonpast-incongruent. A significant main effect of violation is apparent over midline ROIs (F (1, 31) = 7.59, $p = .01$ and over lateral ROIs (F (1, 31) = 5.72, $p < .05$). A comparison with the control sentences (PeriPast control and PeriNonpast-control) was carried out in an overall analysis like the one described in Section 4.3.1 above. Over midline ROIs, this analysis shows a significant interaction of adverb with auxiliary (F (1, 31) = 4.64, $p < .05$), and over lateral ROIs a tendency for an interaction of adverb with auxiliary (F (1, 31) = 3.35, $p = .08$). The interaction allows us to conclude that the positive effect seen after a periphrastic verb which is incongruent with the time reference context is related to the violation and not differences between the periphrastic forms.

To investigate whether the violations by periphrastic verbs are treated the same way as violations by simple verbs, the congruent and incongruent periphrastic forms (first prediction) were compared to the congruent and incongruent simple verb forms (second prediction). Conditions with simple verb forms were correct sentences with a context of the past adverb *zonet*: ('a-moment-ago') followed by a simple verb in past tense with past time reference such as *maalde* 'ground' (SimplePast-congruent), contrasted with sentences with the same past adverb context violated by a verb in present tense with non-past time reference such as *maalt* 'grinds' (condition SimpleNonpast-incongruent). An illustration of the grand average ERP waveforms for correct and violation sentences with simple target verb forms is given in Figure 4.3.

The overall analysis comparing periphrastic and simple verb forms included the factors of verb type (periphrastic versus simple), violation, posteriority and, for the lateral analysis, laterality. There was a main effect of violation (midline analysis: F (1,31) = 10.66, $p < .01$, lateral analysis: F (1,31) = 6.36, $p < .05$), an interaction of verb type with posteriority (midline analysis: F (2,62) = 5.87, $p = .01$, lateral analysis: F (5,155) = 9.57, $p = .01$) and an interaction of verb type with laterality (F (1,31) = 10.33, $p < .01$). There was no interaction between verb type and violation or of the two with distribution factors (all p's > 0.38). The main effect of violation without interactions suggests that the violation is treated the same way for periphrastic and simple verb forms. They both evoke a positivity.

4.3.3 Time window 700-1000 ms

The positive effect of time reference violation by periphrastic verb forms continues in the last time window and becomes larger over posterior electrodes from around 800 ms on (see Figure 4.1). The effect for simple verbs is larger over posterior electrodes (see Figure 4.3).

In the analysis directed at time reference violation by periphrastic verb forms, a significant main effect of violation was found over midline ROIs (F (1, 31) = 4.88, $p < .05$) and over lateral ROIs (F (1, 31) = 5.26, $p < .05$). Furthermore, the factor violation interacted with the factor posteriority over midline ROIs (F (2, 62) = 8.49, $p < .05$) and over lateral ROIs (F (5, 155) = 10.11, $p < .001$). The interaction is caused by the posterior distribution of the effect (see Figure 4.1). The distribution and timing of the positivity are characteristic of the P600. This effect is not seen in the control conditions; in the overall comparison the midline analysis shows a significant interaction of adverb with auxiliary (F (1, 31) = 4.87, $p < .05$) and of adverb with auxiliary and with posteriority (F (2,62) = 5.13, $p < .05$). In the lateral analysis there was a significant interaction of adverb with the factors of auxiliary and posteriority ((F (2, 62) = 6.31, $p < .01$) and a tendency for a main effect of adverb (F (1, 31) = 3.37, $p < .08$). Similar to the previous time window, due to the interactions the conclusion can be drawn that the positive effect seen after a periphrastic verb violation is related to time reference and not the differences between the periphrastic verb forms.

Since this was the case, the effect of violation for periphrastic verbs was again compared to the effect for simple verbs seen in Figure 4.3. The positivity for simple verbs also continues until the end of the time window. The overall analysis comparing periphrastic and simple verb forms shows a main effect of verb type (midline analysis: F (1,31) = 17.91, $p < .001$, lateral analysis: F (1,31) = 22.93, $p < .001$), a main effect of violation (midline analysis: F (1,31) = 6.98, $p = .01$, lateral analysis: F (1,31) = 6.36, $p < .05$), an interaction of violation with posteriority (midline analysis: F (2,62) = 10.01, $p = .001$, lateral analysis: F (5,155) = 10.30, $p = .001$), and an interaction of verb type with posteriority (midline analysis: F (2,62) = 27.16, $p < .001$, lateral analysis: F (5,155) = 20.82, $p < .001$). However, there were no significant interactions between verb type and violation, alone or together with either of the scalp distribution factors (all p's > 0.34).

4.4 Discussion

Consistent with the PADILIH, the time reference difficulties that people with aphasia experience are irrespective of tense. The PADILIH was extended to healthy language use by Dragoy and colleagues (2012), but that study did not clearly show that the difference was between past and non-past time reference rather than past and non-past tense. The goal of the current ERP study was to shed light on whether the positive component in the ERPs evoked by tense violations (Baggio, 2008; Dragoy et al., 2012) is caused by tense per se or by the time reference value of the verb in its context.

4.4.1 Results in relation to the predictions

The first prediction was aimed to address the critical issue. If the P600 reported in studies to tense violations (Baggio, 2008; Dragoy et al., 2012) was not caused by violations of tense as such, but by violations of time reference, a time reference violation which cannot be due to tense should also elicit a P600. As predicted, a violation of past time context (*zonet*: 'a-moment-ago') by a present tense auxiliary evoked a positivity when it signaled a time reference violation. Although the positivity effect seems to start earlier for periphrastic verbs than for simple verbs, this cannot be proven because the effect does not differ from the control sentences until the 500-700 ms time window onwards. Visual inspection showed that initially the effect had a central distribution, which turns more posterior from around 800 ms on and last until the end of the analyzed time windows, matching a P600 effect. The change of distribution is supported by the additional interaction with the scalp factor anterior to posterior in the 700 to 1000 ms time window. The scalp distribution is important, because it suggests that the earlier and later positivities have partially different sources within the brain. The positivity effect is illustrated for the POz-electrode in the upper part of Figure 4.4.

The second prediction was that a violation of past context by a present tense simple verb will be treated as a violation and evoke a P600 effect because time reference and tense cannot be teased apart. This effect was indeed present in the current results for simple verbs, starting around 600 ms and was similar to the effects described by Baggio (2008) and for a slightly different contrast by Dragoy et al. (2012). The P600 effect is illustrated for the POz-electrode in the lower part of Figure 4.4. The effects in the later time windows are clearly comparable.

For conditions with periphrastic verb forms, just as in the second comparison with simple verb forms, the adverb *zonet*: 'a-moment-ago' sets the reference time to some earlier point in the discourse. When an auxiliary comes in (*heeft*: 'has' in condition PeriPast-congruent and *gaat*: 'will' in PeriNonpast-incongruent), the time reference options become clear even before the lexical

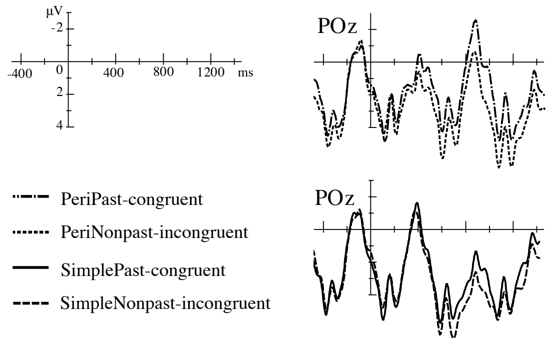

Figure 4.4: ERPs for periphrastic and simple verb forms. The positivity caused by a time reference violation on the auxiliary of periphrastic verbs forms (above) and simple verb forms (below) for POz, a posterior midline electrode.

part of the verb phrase is encountered. When the auxiliary is part of a periphrastic construction that refers to the past (*heeft*: 'has'), the discourse link can be successfully made. No violation of local binding of the present tense occurs, because the time reference expressed through the periphrastic verb form can be set to the past. Thus, the periphrastic past form and the simple past form behave similarly in this respect. However, when an auxiliary inflected with present tense cannot be used for past time reference (e.g., *gaat*: 'will'), there is no possibility for discourse information to render the sentence correct, and a morphosyntactic violation effect (P600) occurs. These results are completely consistent with the first prediction made above on the basis of the PADILIH (Bastiaanse et al., 2011.)

The third comparison was meant to control for any effects caused by the auxiliaries. There is no reason to expect that a P600 effect would occur on the auxiliaries *heeft*: 'has' compared to *gaat*: 'will' in a non-past context. When a non-past temporal context (set by *straks*: 'later') is used, these auxiliaries of time can both be used to build an interpretable temporal model of the sentence. Any difference in this comparison would be due to differences between the auxiliaries, which should then be taken into consideration in interpreting the effects found in the comparison with an incongruent periphrastic verb form. No ERP effect was found upon encountering the auxiliaries. This means that the P600 found on *gaat*: 'will' (compared to *heeft*: 'has') in the past time reference context was not caused by the mere fact that the auxiliaries differ in characteristics such as length, frequency and their visual appearance, but is the result of a violation of time reference.

The results of the periphrastic constructions tested here give us a clear picture. Tense violations only cause a positivity if they lead to an incongruent time reference. In that case they lead to a response which is very similar to the one elicited by the 'tense' violations reported in the literature. This entails that the positivity evoked by simple verb forms such as **maalt*: 'grinds' compared to *maalde*: 'ground', and the positivity found in previous studies (Baggio, 2008; Dragoy et al., 2012) are caused by the time frame that the verb refers to and not by tense. Tense and time reference values may overlap, but they do not always do so. Dutch proved to be a suitable language to disentangle the two. The stimuli of the current study thus provided a testing ground to tease time reference and tense apart.

4.4.2 Sentence-final effects

A last topic to address is what happens at the end of sentences. Both Dragoy et al. (2012) and Baggio (2008) reported a sentence-final negativity. No sentence-final negativity emerged in the current study. Negativities are sometimes seen after conditions in which referential violations occur (Baggio, 2008; Dragoy et al., 2012; Osterhout & Mobley, 1995), but are also occasionally seen after other violations such as gender mismatches (Molinaro, Vespignani, & Job, 2008), gender agreement and semantic violations (Hagoort, 2003b), anomalous lexical items and morphosyntactic anomalies (Osterhout & Nicol, 1999). Taken together, as argued in Dragoy et al. (2012), these negativities do not appear to be specific to referential violations but rather reflect the extent to which processing difficulties can or cannot be resolved. In Dragoy et al. (2012), they appeared after time reference violations, but not after typical N400 and P600 control sentences. It remains unclear whether the lack of sentence-final negativities in the current study is because the violations by periphrastic verbs are different from those by simple forms. However, the analysis in which simple periphrastic and control sentences were all compared did not show any sign of an interaction at the final word in the sentence. Thus, there is certainly no basis to suggest that they do differ systematically.

4.4.3 Conclusion

This study shows that in a context of past time reference, it is the time reference value rather than the tense value of a verb that causes the positivity seen in the ERP responses. Both simple verbs and auxiliaries of time evoke a P600 in such a context. Reference to the past through a present tense auxiliary-participle complex and through past tense can both be used as a baseline in these violations, meaning that they behave similarly.

CHAPTER 5

Losing track of time? Incremental time reference processing[1]

Abstract — *Background*: Individuals with agrammatic aphasia (IWAs) have problems with grammatical decoding of tense inflection. However, these difficulties depend on the time frame that the tense refers to. Verb morphology with reference to the past is more difficult than with reference to the non-past, because a link needs to be made to the past event in discourse, as captured in the Past DIscourse LInking Hypothesis (PADILIH; Bastiaanse et al., 2011). With respect to reference to the (non-discourse-linked) future, data so far indicate that IWAs experience less difficulties as compared to past time reference (Bastiaanse et al., 2011), supporting the assumptions of the PADILIH. Previous online studies of time reference in aphasia used methods such as reaction times analysis (e.g., Faroqi-Shah & Dickey, 2009). So far, no such study used eye-tracking, even though this technique can bring additional insights (Burchert, Hanne, & Vasishth, 2013).

Aims: This study investigated (1) whether processing of future and past

[1]This chapter was adapted from a paper under review as: Bos, L.S., Hanne, S., Wartenburger, I., & Bastiaanse, R. Losing track of time? Processing of time reference inflection in agrammatic and healthy speakers of German. *Neuropsychologia*.

time reference inflection differs between non-brain-damaged individuals (NBDs) and IWAs, and (2) underlying mechanisms of time reference comprehension failure by IWAs.

Methods & Procedures: A visual-world experiment combining sentence-picture matching and eye-tracking was administered to 12 NBDs and 6 IWAs, 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 corresponding pictures on a computer screen.

Conclusions: NBDs scored at ceiling and significantly higher than the IWAs. IWAs had below-ceiling performance on the future condition, and both participant groups were faster to respond to the past than to the future condition. These differences are attributed to a pre-existing preference to look at a past picture, which has to be overcome. Eye movement patterns suggest that both groups interpret future time reference similarly, while IWAs show a delay relative to NBDs in interpreting past time reference inflection. 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.

5.1 Introduction

Individuals with agrammatic aphasia (IWAs) typically show tense processing difficulties (Burchert, Swoboda-Moll, & De Bleser, 2005; Friedmann & Grodzinsky, 1997; Wenzlaff & Clahsen, 2004, inter alia). Several accounts for the problems with tense inflections exist, but recently, the role of the time frame to which is referred — with either tense inflection or other verb forms — has been highlighted. More specifically, verb forms that refer to the past are impaired in agrammatic aphasia, both in production and comprehension (Abuom & Bastiaanse, 2013; Bastiaanse et al., 2011). Based on an extensive data set of aphasiological production and comprehension, the PAst DIscourse LInking Hypothesis (PADILIH; Bastiaanse et al., 2011; Bastiaanse, 2013) was formulated to describe the pattern of selective impairment of past time reference. The PADILIH claims that reference to the past is discourse-linked, regardless of the anaphoric means employed (i.e., not only through tense as suggested by Zagona, 2003). In order to refer to an event in the past, a link has to be made in discourse. The event is then processed by discourse syntax, which is requires more resources and is, therefore, affected in IWAs (Avrutin, 2000, 2006). Events in the here-and-now do not require this link and, hence, reference to this time frame is relatively spared. For future time reference, no discourse-linking is needed either, because the event is not in current discourse. Instead, future time reference is derived from present time reference by modal and aspectual morphemes, as suggested by Aronson (1977), Partee (1973), and Zagona (2013).

Importantly, there is a distinction between tense and time reference. In languages such as German and English, an auxiliary in present tense in combination with a participle can be used for past time reference, such as *hat rasiert*: 'has shaved'. For reference to the future, an auxiliary in present tense combined with an infinitive can be used, such as *wird rasieren*: 'will shave'. The problems of IWAs with reference to the past do not only affect past tense, but all verb forms that refer to the past (Bos & Bastiaanse, 2014). In non-brain-damaged speakers (NBDs), electrophysiological and behavioral responses to time reference violations demonstrate differences between present and past tense processing (Dragoy, Stowe, Bos, & Bastiaanse, 2012). In a follow-up study, Bos, Dragoy, Stowe, & Bastiaanse (2013) showed that these differences are, in line with the PADILIH, not related to tense, but to the time reference of the entire verb form.

Recently it has been shown that eye-tracking studies applying the visual-world paradigm (Allopenna, Magnuson, & Tanenhaus, 1998; Cooper, 1974; for a review of visual world studies see Huettig, Rommers, & Meyer, 2011) can provide insights into language processing in non-brain-damaged speakers, as well as in the online and behavioral performance of aphasic individuals (Dickey, Choy, & Thompson, 2007; Dickey & Thompson, 2009; Hanne, Sekerina, Vasishth, Burchert, & De Bleser, 2011; Meyer, Mack, & Thompson, 2012; Mack, Ji, & Thompson, 2013; Thompson & Choy, 2009; for a review on aphasiological visual-world studies see Burchert, Hanne, & Vasishth, 2013). This technique can clarify what occurs when time reference is interpreted incorrectly in agrammatic aphasia, and whether processing mechanisms differ per time frame.

The following paragraphs review additional relevant literature on agrammatic aphasic comprehension of time reference, and describe previous eye-tracking studies on processing of time reference in NBDs. Furthermore, some of the insights into IWAs' sentence comprehension provided by eye-tracking studies will be discussed.

5.1.1 Aphasiological time reference comprehension studies

Several studies investigated time reference in aphasia, but only a few of them included comprehension tasks. Nanousi, Masterson, Druks, & Atkinson (2006) reported results from grammaticality judgment tasks in Greek including a range of different verb forms: periphrastic future,[2] simple present, past continuous, simple past, and past perfect. IWAs made errors on all tenses. Faroqi-Shah and Dickey (2009) studied online grammaticality judgment of time reference (measuring reaction times) in agrammatic and healthy speakers of English. They did not distinguish between tense and time reference. To test future time reference, their materials included an auxiliary plus infinitive, e.g., *Next year/Last year, my sister will live in Boston.* For present time reference, they included a present tense auxiliary with an infinitive, for example, *These days/last month, my younger sister does not live in Boston*, and a lexical verb in simple present, e.g., *[...] lives [...]*. For past time reference they used a past tense auxiliary with an infinitive, e.g., *[...] did not live [...]*, or a lexical verb in simple past, e.g., *[...] lived [...]*. Response latencies for detecting violations by verbs with future time reference and past time reference were similar and both longer than for those by verbs with present time reference. Accuracy of IWAs did not differ between time frames and was lower than accuracy of NBDs.

Grammaticality judgment data are, however, not informative with respect to the point at which processing breaks down: errors can be due to incorrect processing of the temporal adjunct, the verb, or both. Sentence-picture matching tasks are more revealing in that respect. Jonkers and De Bruin (2009) showed that Dutch-speaking IWAs were more impaired in interpreting past tense inflection than present tense inflection. Bastiaanse and her colleagues (Bastiaanse et al., 2011) studied agrammatic comprehension of time reference using the sentence-picture matching task of the Test for Assessing Reference of Time (TART; Bastiaanse, Jonkers, & Thompson, 2008). This test includes the most frequently used verb forms for reference to the future, present, and past in three languages: English, Turkish and Chinese. The comprehension scores on future time reference were in between those on past and present; past was most difficult for agrammatic IWAs. Similar results were obtained for aphasic speakers of Catalan and Spanish (Martínez-Ferreiro & Bastiaanse,

[2]Nanousi et al. (2006) refer to the periphrastic future with the term 'simple future'.

2013). In a study involving Swahili-English agrammatic aphasic bilinguals, however, participants were selectively impaired in the past condition of the TART only (Abuom & Bastiaanse, 2013). These results suggest that for IWAs, the complexity of discourse-linking leads to errors in past time reference comprehension, whereas accuracy is higher for present. However, performance on future is prone to errors, too. In conclusion, past-time reference is impaired in agrammatic production and comprehension.

5.1.2 Eye-tracking studies manipulating time reference

Several studies demonstrated that eye movements are rapidly influenced by the interpretation of visual events, in particular the time reference deducted from them. In Altmann and Kamide (2007), participants heard sentences with past or future time reference such as *the man will drink...* or *the man has drunk...* while inspecting a panel containing a full and an empty glass, both potential sentence themes. At the onset of the verb phrase, proportions of looks at both objects were similar, but after the verb phrase the participants fixated more often on the full or empty glass in, respectively, the future and past condition. Altman and Kamide thus demonstrated that when healthy speakers of English interpret the time reference of a verb, they direct their gaze towards an object that is anticipated as the grammatical theme.

Also in real world events (with participants watching events acted out by the experimenter), it has been found that time reference guides anticipatory eye movements to the location of the grammatical theme; however, gaze patterns between sentences referring to the past vs. the future differed (Knoeferle, Carminate, Abashidze & Essig, 2011). Participants listened to German sentences in either simple past with past time reference or simple present with future time reference as in (1) while inspecting a scene with two objects.

(1)	Der Versuchsleiter	[zuckert demnächst]/	[zuckerte kürzlich]	die Erdbeeren.
	The experimenter	[sugars soon]/	[sugared recently]	the strawberries.
	'The experimenter will soon sugar/recently sugared the strawberries.'			

During the disambiguating constituents (verb inflection and subsequent temporal adverb), participants preferred to gaze at the object involved in the recently seen event over the object not involved in an event yet. For sentences with future time reference, this recent-event preference was overcome only when hearing the direct object. The authors therewith replicated results of a similar experiment involving clip-art pictures (Knoeferle & Crocker, 2007, Experiment 3). They attribute the preference in looking towards the recently seen object as evidence that even in sentences containing a verb form and temporal adverbial referring to the future, listeners initially prefer to relate the action of a verb to a recently seen event.

The analysis included eye gazes towards two potential target objects for the verb's theme, for example, a plate with strawberries and a plate with a pancake for the verb to sugar. During the disambiguating constituents in both conditions, participants preferred to gaze at the object involved in the recently seen event over the object not involved in an event yet. For sentences with future time reference, this recent-event preference was overcome only upon hearing the direct object. The authors attribute the preference in looking towards the recently seen object as evidence that even in sentences containing a verb and temporal adverbial referring to the future, listeners initially prefer to relate the action of a verb to a recently seen event.

In conclusion, in neutral conditions, NBDs use the interpretation of time reference information to anticipate the object of a sentence. During the verb phrase, NBDs have a preference to inspect the location of a recently seen event, which is overcome when the sentence further unfolds.

5.1.3 Aphasiological eye-tracking studies

So far, no eye-tracking studies have investigated time reference processing in IWAs. However, eye-tracking has been used before in aphasia research and brought interesting insights into how IWAs comprehend sentences. Mack et al. (2013) showed that eye movements of IWAs indicate delayed lexical access during sentence comprehension compared to age-matched healthy adults. Previous studies found that when IWAs interpreted non-canonical sentence structures correctly, eye movement patterns were similar to those of NBDs (passives: Dickey & Thompson, 2009; object-verb-subject sentences: Hanne et al., 2011), although competition with incorrect referents of a clause was sometimes increased towards the end of the sentences (object *wh*-questions: Dickey et al., 2007; object relatives: Dickey & Thompson, 2009; pronominal reference: Choy and Thompson, 2010). In a study by Meyer et al. (2012),[3] eye movement data demonstrated that, compared to NBDs, IWAs are delayed

[3]We refer to the results from IWAs' eye movements split by accuracy in comparison with NBDs.

in processing active and passive sentences even when their offline response (in a sentence-picture matching task) was correct. Dickey and Thompson (2009) proposed that increased processing difficulty with some linguistic structures (such as object relatives in their study) leads to an extra delay in processing in IWAs, which is in line with self-paced listening data from Caplan et al. (2007).

Analysis of the eye-tracking data during comprehension of non-canonical sentences suggests that IWAs initially successfully process these sentences, but sometimes fail to continue to do so as the sentence unfolds: Differences occur close to or after sentence offset (Choy & Thompson, 2010; Dickey et al., 2007; Dickey & Thompson, 2009; Meyer et al., 2012).

5.1.4 Aims of the study

Our first aim was to find out whether NBDs and IWAs differ in correct online processing of future and past time reference inflection (that is, when offline responses on a sentence-picture matching task are correct). We expected NBDs and IWAs to show qualitatively similar eye movements for trials correctly understood by both groups, in line with previous studies demonstrating that IWAs have similar — albeit sometimes delayed — eye movement patterns as NBDs for correctly processed sentences (Dickey et al., 2007; Dickey & Thompson, 2009; Choy and Thompson, 2010; Hanne et al., 2011; Dickey et al., 2007). However, as outlined above, more complex conditions, in our case past time reference, may lead to delays in processing by IWAs versus NBDs (viz. Dickey & Thompson, 2009; Caplan et al., 2007). Since past time reference is discourse-linked and hence more complex, and because it is impaired in aphasia according to the PADILIH, we expected delayed processing reflected in IWAs' eye movement patterns.

The second aim of the current study is to characterize processing patterns reflecting incorrect time reference interpretation. We predicted accuracy on the sentence-picture matching task to be at ceiling for NBDs. For IWAs, we expected equal or below-ceiling accuracy on the future than NBDs, and lower accuracy on the past than on the future, with longer reaction times for past than for future. When IWAs interpret time reference incorrectly, we expect gaze differences as compared to correct trials. Previous studies of non-canonical structures reported systematic differences between correct and erroneous responses (Choy & Thompson, 2010; Dickey et al., 2007; Dickey & Thompson, 2009; Hanne et al., 2011). It is difficult to say a priori what these differences will comprise and when they will arise, since this is the first study to investigate online time reference processing in aphasia within the visual world paradigm.

5.2 Methods

This experiment used the visual world paradigm with combined sentence-picture matching and eye-tracking in order to study the comprehension of past and future time reference inflection in German NBDs and IWAs. Furthermore, the offline comprehension subtest of the TART (Bastiaanse et al, 2008) was administered, which has been used in previous studies (e.g., Abuom & Bastiaanse, 2013; Bastiaanse et al., 2011; Martínez-Ferreiro & Bastiaanse, 2013) and has items for past, present and future.

5.2.1 Participants

There were two participant groups: 12 NBDs (C1-C12; 8 women, mean age 58.0, range 38-77)[4] with no history of neurological, psychiatric, or learning problems and 6 IWAs (B1-B6; 3 women, mean age 57.5, range 41-73). All participants were right handed and native speakers of German, except for B3, who was pre-morbidly left-handed as assessed by the Edinburgh Handedness Inventory (Oldfield, 1971). They all reported normal or corrected to normal vision, and no hearing problems. Each participant signed an informed consent according to the Declaration of Helsinki under a procedure approved by the Ethics Committee of the University of Potsdam. The aphasia of the IWAs was due to a single left-hemisphere lesion, except for B3, who had a right-hemisphere lesion. The IWAs had non-fluent speech output that was effortful and telegraphic, with relative intact comprehension on the Aachen Aphasia Test (AAT; Huber, Poeck, Weniger, & Willmes, 1983). All IWAs' except for B2 were classified as Broca's aphasic using the AAT. B2 was initially diagnosed as Broca's aphasic, but had progressed to anomic aphasic. She exhibited substitutions of plural with single nouns, omissions of determiners and verb forms and sometimes substitutions of finite verb forms with an infinitive in her speech output, and she produced many incomplete utterances. In Appendix C.1, demographic data of the individual participants are provided.

[4] A 13th control participant was excluded because he reported problems with vision, due to the fact that he was not wearing his glasses during the experiment.

5.2.2 Materials and procedure for the TART

Participants were examined with the comprehension subtest of the German version of the TART (Bastiaanse et al., 2008) after the eye-tracking experiment. See Bastiaanse et al. (2011) for a full description of this test. This subtest is a sentence-picture matching task with 60 items: 20 transitive verbs in past, present and future condition. Every sentence was presented auditorily and consisted of three constituents: the subject (man or woman), the verb and the object. For example:

TART-Past	*der Mann hat den Zettel zerrissen*
	(lit. the man-NOM has the paper-ACC torn)
	'the man tore paper'.
TART-Present	*der Mann zerreißt den Zettel*
	(lit. the man-NOM tears the paper-ACC)
	'the man is tearing paper'.
TART-Future	*der Mann wird den Zettel zerreißen*
	(lit. the man-NOM will the paper-ACC tear)
	'the man will tear the paper'.

5.2.3 Materials for the eye-tracking experiment

The stimuli of this study consisted of spoken sentences and pictures. Sentences were presented over a loudspeaker while participants inspected panels with two object pictures (for an example see Figure 5.1). The task was to select the picture that matched the sentence by key press. In a pretest, comprehension agreement for the pictures was tested with 30 university students. Only items with at most two errors were selected, resulting in an overall pretest accuracy of 98%.

Linguistic stimuli

Altogether, there were 60 experimental stimuli: 20 target items in two experimental conditions (Future and Past), and 20 fillers. Additionally, there were six practice items (two of each type). For each item, there was a short introduction sentence in which the subject and object were introduced (see Table 5.1).

The target sentences consisted of an imperative main clause and a subordinate clause, which conveyed the critical time reference information. The

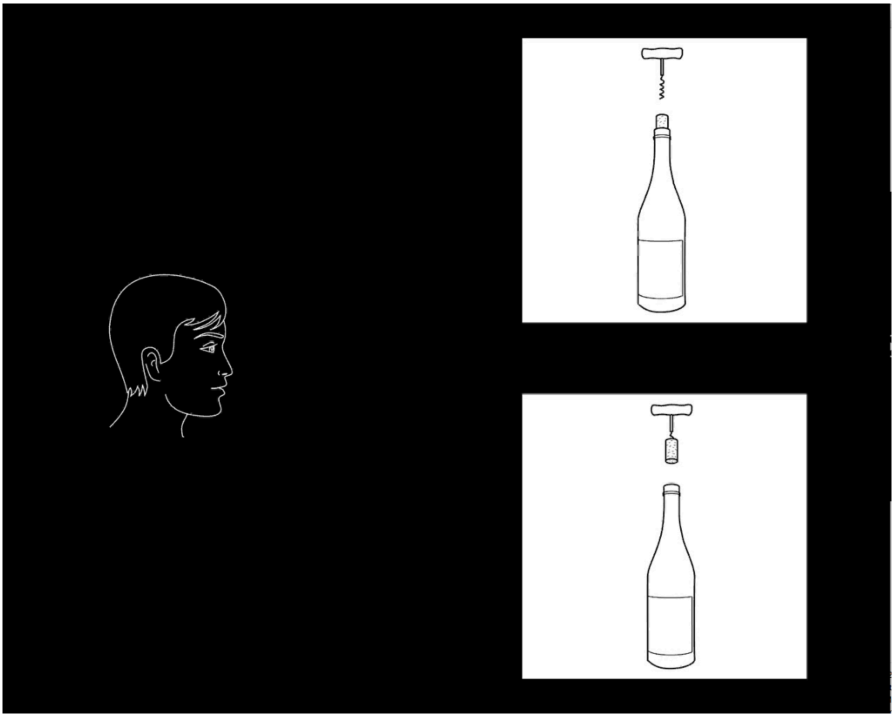

Figure 5.1: Sample visual display, inspired by Altmann and Kamide (2007). This visual display was shown throughout the whole item presentation given in Table 5.1, except the Show-ROI.

subordinate clauses contained transitive weak (regular) change-of-state verbs with an unstressed first syllable, starting with /*be*/-, /*de*/-, /*ent*/-, and /*ver*/-, as well as a set of verbs ending on -/*ieren*/. Each verb was used in both experimental conditions: Future and Past. For the Future condition, a combination of the auxiliary *wird*: 'will' and the infinitive of the lexical verb (periphrastic future). In German, future reference can also be obtained by the simple present, for example *sie fährt morgen*: 'she will drive tomorrow', which is more frequent (Thieroff, 1992). In order to have the inflection appearing at the same position in both conditions, we used subordinate verb-final clauses as target structures. For the Past condition, the periphrastic past (i.e., the present perfect) was used, generated by a combination of the third person auxiliary *hat*: 'has' and

Table 5.1: Auditory regions of interest (ROIs) with their onset times relative to picture and sentence onset, including 200 ms to account for saccade planning. Participants were able to preview the panel from the beginning during the 'SubjIntro' and 'ObjIntro' ROIs for 4000 ms. During the entire 'Show' ROI (500 ms), a smiley was shown centrally on the screen, which is why this ROI is not included in the analysis of eye movements to the target picture. Immediately after the smiley, the picture panel was shown again. The 'Silence' ROI lasted from the offset of the inflection ROI until the participant's response by key press.

Con-dition	**Auditory regions of interest (ROIs) with onset times plus 200 ms (to account for saccade planning)**								
	SubjIntro 201 ms	**ObjIntro 1601 ms**	**Show 4201 ms**	**WhichPic 4701 ms**	**Subject 6521 ms**	**Object 7481 ms**	**Stem [var.]**	**Inflection [var.]**	**Silence [var.]**
Non-	Schauen Sie den Mann	und die zwei Flaschen an.	Zeigen Sie	auf welchem Bild	der Mann	eine Flasche	entkor-	-ken wird.	
past	Look you the man-ACC	and the two bottles at.	Show you	in which picture	the man	a bottle	uncor-	-k will.	
	'Look at the man and the two bottles. Show in which picture the man will open a bottle.'								
Past	Schauen Sie den Mann	und die zwei Flaschen an.	Zeigen Sie	auf welchem Bild	der Mann	eine Flasche	entkor-	kt hat.	
	Look you the man-ACC	and the two bottles at.	Show you	in which picture	the man	a bottle	uncor-	-ked has.	
	'Look at the man and the two bottles. Show in which picture the man has opened a bottle.'								
Filler	Schauen Sie den Mann	und die zwei Flaschen an.	Zeigen Sie	das Bild mit dem Stern.					
	Look you the man-ACC	and the two bottles at.	Show you	the picture with the star.					
	'Look at the man and the two forms. Show the picture with the star.'								

Var = various per item for Stem and Inflection ROI, and additionally per subject for the Silence ROI. Stem ROI onset was 320 ms after the Object ROI offset.

the past participle. This is the usual form to refer to a past event in German. The past participle in German can take different forms, but in the current experiment all verbs used the suffix $-/t/$ on the stem of the lexical verb and no prefix $/ge/$- to mark the participle, for example *lackiert*: 'polished$_{\text{participle}}$'. In German subordinate clauses the verb complex is clause-final and the finite auxiliary follows the participle. Hence, in both conditions, the critical verb inflection appeared at the end of the lexical verb (-*t* in past, -*en* in future condition), before the sentence-final auxiliary. Examples for the introduction and target sentence for both conditions and the fillers are provided in Table 5.1. A complete list of the verbs used in the test is given in Appendix C.2.

The experimental stimuli were partitioned into auditory Regions of Interest (ROIs); see Table 5.1 for examples and their onset times, which was 1 ms after offset of the previous ROI. The introduction sentence consisted of the SubjIntro ROI, in which the subject was introduced, for example: 'Look at the man', and the ObjIntro ROI, in which the object was introduced, for example: 'and the two bottles'. In the Show and WhichPic ROI participants heard the imperative form of to 'show' and the clause 'in which picture', respectively. The Subject ROI consisted of the subject of the subordinate clause (either 'the man' or 'the woman'). The Object ROI contained the subordinate clause's object noun with a determiner, for example: 'the bottle'. The Stem ROI comprised the lexical verb until one phoneme before the onset of the inflection, for example: 'entkor-'. The Inflection ROI encompassed the inflection of the lexical verb and the auxiliary, for example: '-kt hat' for Past or '-ken wird' for Future, and the Silence ROI consisted of the period of silence until the participant responded by key press (see Apparatus and eye-tracking procedure).

Filler sentences had a similar structure until she Show ROI, followed by *das Bild mit*: 'the picture with' and a noun phrase, in some cases with an adjective. Object pictures were semantically related to each other: a tulip served for example as a distractor for the target 'the rose'. Thus, responding to the fillers did not request interpretation of time reference information.

The sentences were recorded monaurally in a sound proof studio from a native, female speaker of German. One recording was used for each experimental lexical verb pair, cross-spliced up to and including the direct object of the experimental sentence. For half of the materials, the verb with past time reference was spliced onto the future sentence, and for half of the materials the verb with future time reference was spliced onto the past sentence. This way, differences in intonation, length, pitch etcetera between the experimental conditions until the critical verb phrase were avoided. In all experimental sentences, timing of presentation of the sentence constituents was manipulated to be similar until the onset of the target object by lengthening or shortening the silence at the end of each ROI.[5] Since lexical verb and object differed per item pair, timing of sentence constituents diverged from the sentence onset, onwards. Between the offset of the object and the onset of the verb phrase, 320 ms of silence appeared. Adobe Soundbooth CS4 (Adobe Systems Incorporated) was used to align the auditory sentence constituents across items and to remove smacks and hisses.

The period between verb onset until the last stem consonant did not differ significantly across conditions (future stem: 411 ms, past stem 423 ms; $t(39) = 1.46$, $p > .05$). The final phoneme of the stem was not included in the Stem ROI, but in the Inflection ROI, to minimize coarticulation effects of the subsequent inflection on the verb stem in this ROI. The Stem ROI duration was matched across conditions by shortening the longest Stem ROI per item pair (in analysis, not in acoustic signal). The mean duration of the final stem phoneme plus the inflection differed between conditions: Future 597 ms (SD = 40 ms) and Past 474 ms (SD = 39 ms; $t(19) = 11.63$, $p = .001$). This was because the lexical verb was not manipulated acoustically. Therefore, the Inflection ROI was lengthened by including silence (mean duration 124 ms) after the auxiliary in the Past condition, equaling its duration to that of the Future condition.

Visual stimuli

Pairs of black-and-white line drawings were developed in Adobe Illustrator CS4 (Adobe Systems Incorporated) depicting the object of each subordinate clause in Future and Past condition, respectively, or two semantically related objects for the filler items. For the Future condition, the object was depicted in the state before the event (e.g., an unopened wine bottle for ‘to uncork’), whereas for the past condition the object was depicted in the state after the event (e.g., an open wine bottle for ‘to uncork’). The two object pictures were placed one above the other. In addition to the two pictures of the object, the subject of the sentence (either a man or a woman) was depicted to the left hand side of the object pictures. Figure 5.1 shows a sample of the visual display for the

[5]The manipulation of the silence at ROI (i.e. constituent) boundaries was kept to a minimum, because the lexical material until object onset was the same in all experimental sentences. No participant reported that items sounded unnatural.

experimental sentences of Table 5.1.

5.2.4 Apparatus and eye-tracking procedure

A table-mounted remote Tobii T120 (Tobii Technology AB, Stockholm, Sweden) eye-tracking system was used to track at a sampling rate of 60Hz in a double computer solution (binocular tracking, accuracy: 0.5 degrees, head-move-tolerance: 30 x 22 x 30 cm). Picture panels were presented on the screen of the eye-tracker (screen size: 17 inch, resolution: 1280 x 1024 pixels) in an AVI-file with CINEPAK codec created in Adobe Flash CS4 (Adobe Systems Incorporated) using Tobii Studio software 1.7.2 (Tobii Technology AB), which was also used for data collection.

The practice trials were administered on paper by the experimenter before the eye-tracking experiment and repeated if the participant made an error. Then, the participants were seated in a comfortable chair approximately 60 cm in front of the monitor and performed the sentence-picture matching task. They were asked to press the upper arrow key with the index finger or the lower arrow key with the thumb of their non-dominant hand to indicate whether the upper or lower picture, respectively, matched the sentence. Maximum response time was set at 10 seconds after sentence offset. The picture size was 410 x 410 pixels for the target and foil object picture and 190 x 240 pixels for the picture of the subject (man or woman). After a 9-point calibration procedure, during which red dots were displayed on a black screen, the online practice phase started. Calibration was repeated before the beginning of the test phase and after a 5-10 minute break halfway during the experiment. Total testing time with the eye tracker was between 15 minutes and 30 minutes. Eye movements, accuracy and response time (from the onset of the object NP of the subordinate clause) were measured.

Two pseudo-randomized presentation lists were constructed in which no more than two adjacent items were of the same condition, and in which the initial item after calibration and every third one following was a filler item. Each verb (with corresponding pictures) appeared twice in the experiment, therefore, the first and second occurrences of a verb were spread evenly over conditions. Between two occurrences of the same verb, an average number of 24 trials appeared (range 9-41). Fillers appeared at the same trial position across lists, but conditions of a verb were alternated to create two counter-balanced lists. Target picture placement (upper vs. lower) was balanced (10:10 across conditions including fillers) and pseudo-randomized so that maximally three consecutive targets were located at the same position. For filler sentences, half of the object pictures were targeted twice to discourage developing a strategy of clicking on the not-yet-targeted picture.

The picture preview was shown for 4000 ms during which the introduction sentence was played conveying information on the three pictures in the panel, including a 1000 ms break before the critical sentence starts. The experimental sentence started with the Show ROI, during which the presentation of the visual display was interrupted and instead a smiley appeared for 500 ms in the middle of the screen to center the participant's gaze before the onset of the critical sentence constituents. The critical object started at 7280 ms in all the experimental sentences. Timing of the ROIs is indicated in Table 5.1.

5.2.5 Data analysis

To analyze the data, linear mixed-effects regression analyses were carried out using the *lmer* function of the *lme4* package (Bates, Maechler, & Bolker, 2013) in R (R Core Team, 2013). Eye movement plots were assembled using the *ggplot2* function 0.9.3.1 (Wickham & Chang, 2013). In the regression models, we included random effect predictors for participants and items, and the most significant random slopes that still yielded a converging model. Stepwise model comparison was based on the Akaike Information Criterion (AIC): predictors were deleted if that did not increase the AIC and if that resulted in a converging model. Absolute t- and z-scores greater than 1.96 were considered significant.

For the analysis of the TART data of IWAs,[6] we used logit-linked accuracy (1 = correct, 0 = incorrect). We compared condition predictor levels (TART-past, TART-present, and TART-future) to each other using post-hoc Tukey's contrasts. Model comparisons tested the significance of by-participant and by-item random slopes for predictors Condition and Trial number, as well as fixed effects and an interaction between those predictors.

For the eye-tracking experiment, behavioral and eye movement analyses included the predictor Participant group, for which we coded NBDs as baseline category (0) to which IWAs (1) were compared. The coding contrast for the Condition predictor was 0 for future and 1 for past. A Baseline picture pref-

[6] NBDs scored at ceiling on the TART and these data were further ignored.

erence predictor[7] was calculated for each participant and trial based on the proportion of looks to the past versus the future target picture in ObjIntro ROI, in which participants were asked to inspect both object pictures. This was done to account for any a priori minor differences in visual attractiveness of the stimuli. Values ranged between 0 (no past picture preference) and 1 (only looks to the past picture) with mean 0.52, which means that averaged over trials, the participants inspected both pictures almost equally long during the ObjIntro. However, for a given trial participants might have preferred the past picture (this will be discussed below).

For the behavioral analyses of the eye-tracking data we used (a) logit-linked accuracy (1 = correct, 0 = incorrect) and (b) log-transformed correct response times from the object onset onwards. Model comparisons tested the significance of by-participant and by-item random slopes for Participant group (only by-item), Condition, Trial number (i.e., the numerical position of the trial within the presentation list), Picture repetition (i.e., first and second appearance), Baseline picture preference, and Age, as well as fixed effects of those factors.

For analyses of eye-movements, saccade planning was accounted for by shifting the duration of all ROIs 200 ms forward, which has been shown to be sufficient for both NBDs and IWAs (Altman & Kamide, 2004; Dickey, Choy, & Thompson, 2007). IWAs' data were partitioned into correct and incorrect responses. The dependent variable of the eye movement models was the proportion of looks to the target versus the foil object picture with random effect factors for participants and items. The full model contained the fixed effects of Participant group, Condition, ROI, Trial number, Picture repetition, and Baseline picture preference. For the ROI predictor, successive backwards difference coding was used, comparing the fixation proportion of each ROI to that of the preceding one, from the Subject ROI (versus the WhichPic ROI) onwards.

The distribution of the statistical models' residuals for the eye-tracking data was visually inspected using quantile-quantile plots for close adherence to the diagonal line. In addition, the standardized residuals were analyzed. The assumption of normality was met, meaning that 5% or less of the standardized residuals of the model had a z-score of 1.96 or greater, a maximum of 1% of them a z-score of 2.58 or greater, and none of them a z-score of 3.29 or greater.

[7] The results reported are obtained with an uncentered predictor, because centering lead to convergence problems for some models. However, leaving the predictor uncentered was justified because the zero point was meaningful and for the converging models the overall results are not different from when a centered predictor was used.

5.3 Results

The mean accuracies and response times are shown in Figure 5.2 and plots of the proportion of eye movements to the correct versus foil object picture Figure 5.3. Individual accuracies and response times per participant can be found in Appendix C.3.

5.3.1 TART

The NBDs scored at ceiling in all three conditions of the TART (past, present, future) and we did not analyze these data any further. The model that best described the IWAs' data contained random effects for items and participants, with a random slope for condition per participant. Furthermore, it contained a fixed effect of Trial number, the slope of which was not significant ($\beta = 0.01$, $SE = 0.01$, $z = 1.21$), and Condition. Tukey's contrast showed that the TART-past and TART-future both differed significantly from the TART-present, but not from one another (TART-past versus TART-present: $\beta = 2.87$, $SE = 0.86$, $z = 3.35$; TART-future versus TART-present: $\beta = 2.63$, $SE = 0.75$, $z = 3.53$; TART-past versus TART-future: $\beta = 0.24$, $SE = 0.36$, $z = 0.66$).

5.3.2 Accuracy and RTs online sentence-picture matching

The best-fitting random effect structure for accuracy contained the random effects of Participant and Item without random slopes. Model AIC comparisons revealed a two-way interaction between the fixed factors of Participant group and Condition. Overall, IWAs responded less accurately than NBDs ($\beta = 3.09$, $SE = 0.63$, $z = 4.92$). There was no overall difference between the Future and Past condition ($\beta = 0.98$, $SE = 0.68$, $z = 1.43$), however, the interaction indicated that the difference between conditions was significantly larger for IWAs than for NBDs, meaning that IWAs were less accurate on Future than on Past ($\beta = 2.06$, $SE = 0.87$, $z = 2.36$).

The best-fitting random effect structure for log-transformed response times for correct responses contained random slopes for Condition by Participant, and for Participant group interacting with Picture repetition by Item. Model comparisons revealed main effects of Participant group and Condition and a main effect of Picture repetition. Overall, IWAs responded slower than NBDs

($\beta = 0.31$, $SE = 0.05$, $t = 6.21$). Responses to the Past condition were overall faster than to Future condition ($\beta = 0.12$, $SE = 0.02$, $t = 5.04$). Participants of both groups responded faster when they saw a picture for the second versus the first time ($\beta = 0.03$, $SE = 0.01$, $t = 2.86$).

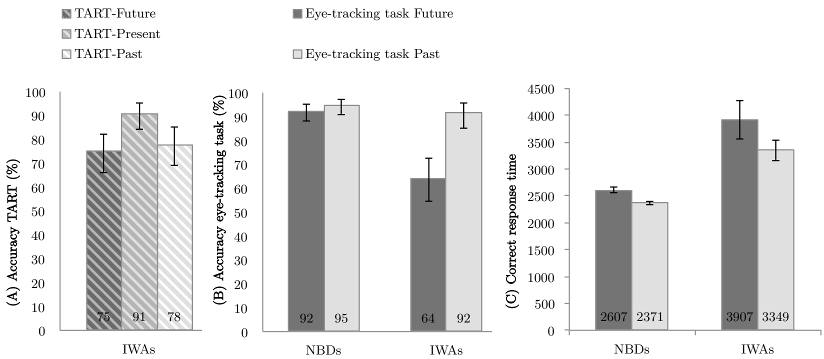

Figure 5.2: Overview of the accuracy (A) of IWAs on the TART, and the accuracy (B) and correct response times (C) of key presses in the sentence-picture matching task of the eye-tracking experiment. The response time is calculated from the object onset onwards.

5.3.3 Eye movements

First, correct data of NBDs versus IWAs were analyzed. The proportion of looks to the target versus the foil object picture per ROI was the dependent variable. The best-fitting random effect structure for correct answers contained random slopes for the Baseline picture preference interacting with Condition by Participant, and for Baseline picture preference and Picture repetition by Item. Model comparison revealed a three-way interaction between the fixed factors of Participant group, ROI, and Condition. There was an overall (i.e., over ROIs and participants) higher proportion of looks to the target picture in the Past than in the Future condition ($\beta = 0.12$, $SE = 0.02$, $t = 6.14$). Across both participant groups, the proportion of looks changed significantly from the previous ROI in the Inflection ROI ($\beta = 0.14$, $SE = 0.03$, $t = 4.16$) and in the Silence ROI ($\beta = 0.24$, $SE = 0.03$, $t = 7.06$). During the Silence ROI, the overall increase (i.e., for both groups) in proportion of looks to the target picture compared to the previous ROI was smaller for the Past condition than

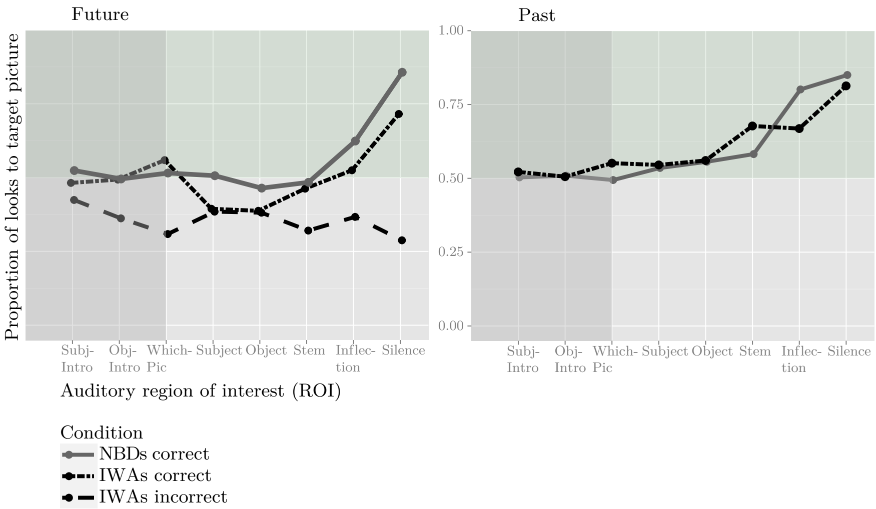

Figure 5.3: Eye movement plots. The statistical analysis included ROIs from WhichPic onwards (non-shaded). Past incorrect is not shown for IWAs, because there were not enough data for analysis.

for the Future condition ($\beta = 0.17$, $SE = 0.05$, $t = 3.28$). To interpret the three-way interaction in the model, the data were broken down along the variable Condition, while keeping the remaining model the same and with both models including the variables of Participant group and ROI.

Future condition: For the correct responses to the Future condition, model comparison showed main effects of Participant group and ROI, but no interaction between them. Overall, the IWAs looked less towards the future target picture than NBDs ($\beta = 0.07$, $SE = 0.02$, $\mathrm{t} = 3.13$). For both groups, the proportion of looks towards the target picture increased with respect to the previous ROI during the Inflection ROI ($\beta = 0.11$, $SE = 0.03$, $t = 4.13$) and during the Silence ROI ($\beta = 0.24$, $SE = 0.03$, $t = 8.53$).

Past condition: The analysis of correct responses to the Past condition revealed an interaction between Participant group and ROI ($\chi^2\,(5) = 20.48$, $p < .01$). The proportion of looks towards the target picture increased significantly with respect to the previous ROI during the Inflection ROI ($\beta = 0.22$, $SE = 0.03$, $t = 6.95$) and Silence ROI ($\beta = 0.07$, $SE = 0.04$, $t = 1.95$). IWAs showed a less steep increase in looks towards the past target picture compared to NBDs upon hearing the Inflection ($\beta = 0.23$, $SE = 0.06$, $t = 4.11$) as revealed by the interaction.

Correct and incorrect responses: In a separate analysis on IWAs' eye movement proportions, both correct and incorrect responses to the Future condition were included as factor Accuracy – this analysis was not performed for the Past condition, because of their high accuracy and resulting lack of sufficient data points. The random effect structure was the same as for the participant group analysis above, excluding condition as a random slope. The best fitting converging model contained a two-way interaction between the fixed factors of ROI and Accuracy. The proportion of looks towards the target picture was overall higher for correct responses than for incorrect responses ($\beta = 0.14$, $SE = 0.03$, $t = 4.40$). In the Silence ROI compared to the previous ROI, there was a marginally significant increase in this difference in proportions ($\beta = 0.18$, $SE = 0.10$, $t = 1.84$).[8]

5.3.4 Summary of the results

The outcomes of the TART showed that the IWAs are impaired in comprehension of past and future time reference inflection, while comprehension of present time reference inflection is relatively intact. As expected, NBDs showed no comprehension problems on this test. In the behavioral data of the eye-tracking experiment, the only below-ceiling accuracy was performed by IWAs on the Future condition. Response times of NBDs and IWAs were longer for the Future than for the Past condition. The eye movement analysis showed that NBDs and IWAs processed future time reference similarly, but IWAs were relatively delayed on processing past time reference inflection. In both groups, there was an overall preference to look towards the target past picture. Incorrect parsing of the Future time reference condition was reflected in a great number of looks to the non-target past picture and finally resulted in incorrect key presses.

[8] In the Subject ROI versus the previous ROI, correct responses had a marginally significant smaller increase in looks towards the target picture as compared to incorrect responses ($\beta = 0.19$, $SE = 0.10$, $t = 1.90$). Since the Smiley ROI — during which a smiley instead of the picture panel was shown — precedes the subject, it is unlikely that this early difference is meaningful and it will be further ignored.

5.4 Discussion

With the current study we aimed to reveal (1) whether NBDs and IWAs differ in correctly processing future and past time reference inflection, and (2) what processing patterns underlie incorrect time reference interpretation in IWAs. According to the PADILIH, for the interpretation of past time reference, discourse-linking is needed — but not for future time reference interpretation. Discourse-linking requires additional processing resources at the level of discourse syntax, and this is what lacks in IWAs (Avrutin, 2000, 2006). We will discuss both aims below and will show that our results are in line with the tenets of the PADILIH. We will then discuss the TART data.

5.4.1 Correctly interpreted time reference in NBDs vs. IWAs

Our first aim was to characterize differences between NBDs and IWAs in correctly processing future and past time reference inflection. Eye movement patterns in the Future and the Past condition differed overall in both groups, which was expected on the basis the behavioral responses in this experiment (longer RTs and, for IWAs, lower accuracy in the Future than in the Past condition). However, interesting with respect to the PADILIH is that the NBDs and IWAs had similar eye movements when sentences were processed correctly in the future time reference condition, yet when they processed past time reference inflection, the IWAs showed a delay with respect to NBDs, reflected in an increase of their looks to the target picture one ROI later (Silence ROI). This is in line with our predictions based on previous eye-tracking studies (Dickey et al., 2007; Dickey & Thompson, 2009; Choy and Thompson, 2010; Hanne et al., 2011; Dickey et al., 2007) and the notion that IWAs generally require more time to process more complex materials (Caplan et al., 2007; Dickey & Thompson, 2009). As a result of a processing deficit (Caplan et al., 2007), IWAs show a delay in interpreting the inflection for past, because access to discourse structure is impaired in IWAs (Avrutin, 2006). This delay in processing past time reference inflection is paradoxical when the RTs of the picture selection task are taken into account: In the remainder of this section we will discuss how this paradox can be resolved.

In correct trials, there was a longer response time to Future than to Past stimuli in both participant groups: a difference of 235 ms for NBDs and of 558 ms for IWAs — without an interaction between Participant group and Condition. Part of this difference can be ascribed to the fact that the future verb form typically has one syllable more than the past verb form. The future verb forms (stem and inflection) were 111 ms longer than the past verb forms.[9] This length difference is a limitation of our choice not to manipulate the phonetic signals in order to keep the natural characteristics of the suffix in the future condition. Another source of this increased response time may be the fact that for past reference, we used the most frequent spoken verb form, while for future reference we used the periphrastic future, although in German the simple present is most frequently used to refer to the future (Thieroff, 1992). However, as frequency of use of grammatical constructions does not to play a major role in performance of IWAs (see Bos & Bastiaanse, 2014; Martínez-Ferreiro, 2013; Bastiaanse, Bouma, & Post, 2009; Faroqi-Shah & Thompson, 2004), we assume this is not the correct explanation.

Instead, we argue that the increased duration in response times in the future condition should be attributed to the pre-existing advantage to look at the past over the future picture. This is visible in Figure 5.3 as the difference between the lines for future and past in both participant groups.[10] This preference has to be overcome for future reference interpretation, thus leading to increased response times in both participant groups.

The past picture preference which we found in our study has not been reported in earlier studies. In their study with NBDs, Altmann and Kamide (2007) used few change-of-state verbs in their materials and, moreover, they showed pictures of two different objects, for example, a wine glass and a beer glass, so that no prototypical past picture was included. However, Knoeferle et al. (2011) found that locations of recently seen events attract more eye gazes during verb processing than potential target locations of future events. This finding is similar to the past-picture preference observed in our study. Nevertheless, some important differences in experimental design between our study and Knoeferle et al.'s suggest different causes of the past picture preference. Knoeferle et al. used real-world events, while in the current experiment no events were depicted — only the state of the object before and after the event

[9]Note that for the eye movement analysis the ROI durations were adjusted per condition, so that this difference is only of importance to the response time analysis.

[10]It is important to note that the backwards difference coding we applied for the ROI predictor in the statistical analyses limits the influence of pre-existing picture preferences in the analysis and interpretation of the eye movement data. However, Picture repetition was accounted for in the by-item random slopes of the model.

was shown. In addition, in Knoeferle et al., no particular task was given and the verb occurred before the sentential object, so that looks to the event locations were anticipatory and reflecting incremental sentence comprehension. In our experiment, however, participants were asked to select the appropriate object picture, which was mentioned in the target sentence before hearing the verb form. Earlier looks towards the object pictures may, therefore, reflect a hypothesis driven guess on which lexical verb was going to be used. Crucially, a past picture contains more relevant information, because it shows the result of the event of a change-of-state verb and this makes past pictures more salient as compared to pictures showing future events. See for example Figure 5.4, with the pictures used for the verb *verbeulen*: 'to bump'. Thus, in contrast to in Knoeferle et al., where the recent-event preference was a direct manifestation of anticipatory eye movements during incremental language processing, the past picture preference in our study may have been caused by features inherent to the materials used and could be a result of attraction to more salient visual information.

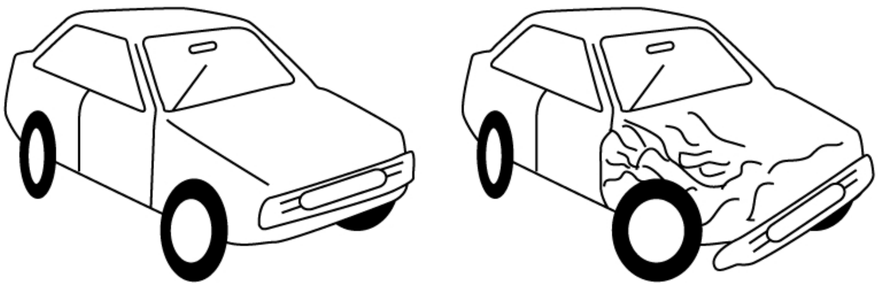

Figure 5.4: Pictures of a car used for the items with *verbeulen*: 'to bump'. The left one served as target for the Future condition, the right one for the Past condition.

To summarize, NBDs and IWAs were slower to press the correct key in the Future than in the Past condition, which can be ascribed to a past picture preference. Crucially however, IWAs were delayed with respect to the NBDs in interpreting past time reference inflection reflected in a delay directing their gaze to the target picture. Contrastingly, directly upon hearing future time reference inflection both groups interpreted it, reflected in increased gazes to the target picture.

5.4.2 Incorrect time reference processing

The second aim was to characterize underlying mechanisms of time reference comprehension failure of IWAs. The TART showed that the German IWAs were similarly impaired in comprehension of future and past time reference compared to present time reference. Surprisingly, comprehension scores and response times in the eye-tracking experiment suggested that past time reference is easier than future time reference for these IWAs. However, the preference to look at the past picture before the critical inflection has been heard and the tendency not to switch to the other picture must have played a role. While NBDs successfully overcame this looking preference, IWAs were struggling in doing so. For sentences in the past condition, IWAs already looked at the target (past) picture more often before the inflection was perceived, so that no preference had to be overcome and, hence, they were less prone to make errors compared to the future condition. This idea is in line with recent suggestions on cognitive processing in aphasia ascribing an enhanced role to task-demands and task-effects on language comprehension performance in IWAs (Caplan, Michaud, & Hufford, 2013).

The accompanying eye movement patterns reveal that for incorrect responses in the future condition, IWAs fixated overall more on the non-target (i.e., the past) picture than in the correct condition. During the silence between sentence offset and response, the gaze patterns for correct and incorrect responses show a tendency to diverge. The data in Figure 5.2 suggest that during correct processing, IWAs further increase their looks to the target picture, while during incorrect processing, they increase their looks to the non-target past picture. In other words, when IWAs process future time reference incorrectly, they are looking to the incorrect (i.e., past) picture early on in the sentence, they fail to switch their attention (reflected in their gaze) to the correct picture, and finally they select the wrong picture.

A question that remains is why the IWAs do not show a similar past picture advantage in the TART. Some differences between the procedure and materials of the TART and the eye-tracking experiment are relevant with regards to this question. First, there was time pressure during the eye-tracking task, but not during the TART. Furthermore, with respect to the sentences used, the position and order of the verb phrases is different, because the TART uses main clauses with the finite verb (simple present lexical verb or auxiliary) appearing before the object, which precedes the infinitive/participle. In contrast, the eye-tracking experiment used embedded sentences with a sentence-final complex consisting of an auxiliary and lexical verb. Putting the verb inflection relevant for the interpretation at the end of the sentences and adding time pressure may have increased the working memory load which is limited in IWAs (Caplan et al., 2007).

5.4.3 Conclusion

In the eye-tracking experiment, sentences with verb forms referring to the future were more difficult than sentences with verb forms referring to the past for both participant groups, as demonstrated by accuracy and response time. The important finding of our study is that IWAs interpret future time reference similarly to NBDs, as demonstrated by eye movement patterns during and after the verb phrase. However, IWAs' interpretation of past time reference inflection is delayed compared to NBDs, as revealed by eye movement patterns during and after the verb phrase. The latter finding supports the PADILIH that postulates that processing discourse syntax requires additional resources and is, therefore, problematic for people with aphasia. When IWAs make errors on sentences with future time reference, eye movement patterns suggest that these errors arise because IWAs fail to overcome the past-picture preference and to switch their attention to the future target picture at the end of the sentence. Since in NBDs as well as IWAs the past-picture preference emerged early in the sentence, before the time reference inflection, it does not relate to processing of time reference inflection.

Further aphasiological research may clarify how online processing of present and past time reference differs. Furthermore, generalizability of the current results to other languages and verbs should be investigated, because the current study employed change-of-state verbs without the typical prefix *ge-* on the participle.

CHAPTER 6

Conclusions and further research directions

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,[1] 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

[1] 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; Wieczorek, 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; Faroqi-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*$_{present\ tense}$ *gegeten]*$_{past\ time\ reference}$: '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 performed 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; Zagona, 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.

Appendix

A Appendix to chapter 2: Understanding discourse-linked elements in aphasia

A.1 Individual Russian participant characteristics

Table A.1.1: Individual Russian participant characteristics.

Pp	Sex	Age	Education	Aphasia type	Time PO	Etiology	Location of lesion	Hemiplegia
Agrammatic aphasic participants								
A1	f	43	higher	efferent / mild dynamic, medium	5y	hCVA	left temporo-parietal	right
A2	m	35	higher	efferent (Broca), medium	4m	hCVA	arteriovenous malformations left temporo-parietal	right
A3	f	46	higher	efferent (Broca)	2y / 5m	CVA	left middle cerebral artery	right
A4	f	36	higher	dynamic	2y	iCVA	left middle cerebral artery thrombosis, post-stroke changes in left frontoparietal-temporal region	right
A5	f	38	secondary	efferent, medium	2y	TBI	subarachnoid - parenchymal left	no
A6	m	66	secondary	mild efferent	1y / 4m	CVA	left middle cerebral artery	right
A7	f	37	higher	mild efferent	5y4m	CVA	left middle cerebral artery	right
A8	m	53	secondary	efferent, dynamic	1y9m	CVA (mixed)	origin in the left middle cerebral artery	no
A9	m	44	secondary	afferent, efferent	8m	CVA	cortico-subcortical left frontal, parietal and temporal	no
A10	f	37	secondary	dynamic, efferent, afferent	2y10m	CVA after aneurysm	anterior and middle cerebral arteries	right
Fluent aphasic participants								
F1	f	57	secondary	sensory / acoustic-mnestic	2y3m	CVA	left middle cerebral artery	no
F2	f	68	higher	sensory	4.5m	iCVA	left parietal region, with impregnation	no
F3	m	55	higher	sensory	7y2m	CVA	left middle cerebral artery	no
F4	m	59	higher	sensory	3m	iCVA	left temporo-occipital region	no

Pp	Sex	Age	Edu-cation	Aphasia type	Time PO	Etiology	Location of lesion	Hemi-plegia
F5	f	58	higher	sensory	1y10m /2y2m	subarachnoid hCVA/intra-cerebral hematoma	right temporal lobe, 4.5 months later aneurysm clipping left hemisphere	no
F6	m	65	secondary	severe sensory	7m	iCVA	left internal carotid artery, vascular-alcoholic genesis	no
F7	m	48	secondary	medium / severe sensory, acoustic-mnestic	3m	CVA	left middle cerebral artery	no
F8	m	22	incomplete higher	medium-severe sensory / acoustic-mnestic	2y4m	TBI	intracerebral hematoma of the left parietal region, midline shift of the brain	no
F9	m	65	higher	sensory / acoustic-mnestic	4y6m	CVA	left parietal / signs of lacunar strokes basal ganglia right	no
F10	f	55	higher	sensory	1y2m	hCVA	post-hemorrhagic cyst left temporo-parietal-occipital	no
Non-brain-damaged participants								
C1	f	28	higher					
C2	f	48	higher					
C3	f	53	higher					
C4	m	22	incomplete higher					
C5	f	49	higher					
C6	f	74	secondary					
C7	m	47	higher					
C8	f	55	higher					
C9	f	31	higher					
C10	m	32	higher					

Pp = participant; Time PO = Time post-onset; y = years; m = months; hCVA = hemorrhagic cerebrovascular accident; iCVA = ischemic cerebrovascular accident; TBI = traumatic brain injury.

A.2 Verbs used in the Russian tests

Table A.2.2: Verbs used in the Russian aphasia tests (plus object nouns of TART).

TART				RePro		WHEAT	
Russian verb	**Russian noun**	**Transl. verb**	**Transl. noun**	**Russian verb**	**Transl. verb**	**Russian verb**	**Transl. verb**
vymyt'	pol	to mop	floor	vzveshivat'	to weigh	vzveshivat'	to weigh
podmesti	pol	to sweep	floor	vytirat'	to dry	vytirat'	to dry
vypit'	moloko	to drink	milk	katat'	to kart	gladit'	to stroke
nalit'	moloko	to stir	milk	kachat'	to swing	nakryvat'	to cover
napolnit'	papku	to fill	folder	myt'	to soap	nesti	to carry
osvobodit'	papku	to empty	folder	nakryvat'	to cover	obuvat'	to put-shoes-on
narisovat'	kvadrat	to paint	square	oblivat'	to splash on	odevat'	to dress
nachertit'	kvadrat	to draw	square	obuvat'	to put-shoes-on	ostanavlivat'	to stop
pogladit'	sviter	to iron	sweater	odevat'	to dress	podnimat'	to lift
slozhit'	sviter	to fold	sweater	osvobozhdat'	to free	presledovat'	to chase
podt'anut'	telezhku	to pull	kart	podnimat'	to walk up	priv'azyvat'	to tie
tolknut'	telezhku	to push	kart	podstrigat'	to cut	pr'atat'	to hide
porvat'	bumagu	to tear	paper	prist'ogivat'	to fasten	razgl'adyvat'	to investigate
prikleit'	bumagu	to glue	paper	pr'atat'	to hide	razdevat'	to undress
potochit'	karandash	to sharpen	pencil	razdevat'	to undress	raschesyvat'	to comb
slomat'	karandash	to break	pencil	raschesyvat'	to comb	tolkat'	to push
pochistit'	jabloko	to peel	apple	spuskat'	to walk down	fotografirovat'	to photograph
s'est'	jabloko	to eat	apple	umyvat'	to wash	zelovat'	to kiss
sv'azat'	koftu	to knit	shirt	fotografirovat'	to photograph	schekotat'	to tickle
sshit'	koftu	to sew	shirt	chistit'	to brush	schipat'	to pinch

A.3 Accuracy per Russian aphasic participant

Table A.3.3: Individual Russian aphasic participant accuracy, calculated over 20 items per condition for the TART and WHEAT, and 40 items for the RePro. The non-brain-damaged control participants did not make any errors.

	TART		**RePro**		**WHEAT**	
	PastPerf (%)	**PresImp (%)**	**Pro (%)**	**Refl (%)**	**Who (%)**	**Which (%)**
A1	70.0	100.0	92.5	87.5	80.0	60.0
A2	85.0	100.0	100.0	100.0	100.0	100.0
A3	70.0	95.0	100.0	100.0	40.0	85.0
A4	85.0	100.0	100.0	100.0	95.0	85.0
A5	85.0	100.0	97.5	100.0	100.0	95.0
A6	55.0	90.0	95.0	80.0	55.0	40.0
A7	95.0	100.0	100.0	100.0	90.0	60.0
A8	45.0	90.0	100.0	100.0	100.0	90.0
A9	90.0	100.0	100.0	97.5	100.0	100.0
A10	70.0	95.0	97.5	97.5	100.0	65.0
Mean	*75.0*	*97.0*	*98.3*	*96.3*	*86.0*	*78.0*
F1	75.0	100.0	100.0	95.0	100.0	95.0
F2	75.0	90.0	85.0	92.5	35.0	60.0
F3	85.0	100.0	97.5	97.5	80.0	85.0
F4	95.0	100.0	95.0	100.0	35.0	10.0
F5	50.0	95.0	82.5	90.0	70.0	55.0
F6	60.0	65.0	57.5	85.0	50.0	60.0
F7	95.0	95.0	97.5	97.5	100.0	60.0
F8	95.0	100.0	100.0	100.0	100.0	85.0
F9	85.0	95.0	100.0	100.0	90.0	90.0
F10	95.0	100.0	100.0	100.0	65.0	40.0
Mean	*81.0*	*94.0*	*91.5*	*95.8*	*72.5*	*64.0*

B Appendix to chapter 3: Time reference decoupled from tense in aphasia

B.1 Individual Dutch aphasic participant data

Table B.1.1: Individual Dutch aphasic participant characteristics.

Participant	Age	Sex	Hand	(Former) profession	Speech rate w/m	Aetiology	Time PO	BDAE
Agrammatic aphasic speakers								
B1	50	F	R	Cleaning lady, housewife	22	iCVA left	8 m	72
B2	56	M	R	Software designer	37	iCVA left ACM	7 m	72
B3	42	F	R	Office employee	27	iCVA left frontoparietal and smaller right parietal	3 y 4 m	68
B4	49	F	R	Elderly caretaker	42	iCVA left	5 y 4 m	71
B5	76	M	R	Architect	70	iCVA left ACM	4 y	66.5
B6	56	F	R	Canteen manager	87	iCVA left ACM	3 y 6 m	64
B7	49	M	R	Mechanical engineer	46	iCVA left with hemorrhagic component	5 y 9 m	66
B8	58	M	R	History teacher	40	iCVA left ACM and capsula interna	5 y 6 m	65.5
B9	40	F	R	Bookkeeper	29	iCVA left ACM	4 y	69
B10	56	M	R	Logistic manager	68	iCVA left ACM	4 y 6 m	64
B11	78	M	R	Technical manager	56	iCVA left ACM	15 y	72
B12	63	M	L	Constructional calculator	51	iCVA left	1 y	72
B13	67	F	R	Guesthouse owner	20	iCVA left frontoparietal ACM	6 m	60
B14	39	M	R	Carpenter historic buildings	34	iCVA left ACM	1 y 2 m	72

Parti-cipant	Age	Sex	Hand	(Former) profession	Speech rate w/m	Aetiology	Time PO	BDAE
Fluent aphasic speakers								
F1	41	M	R	Construction worker	111	iCVA left	4 m	72
F2	66	M	R	Navy officer	119	iCVA left ACM	10 m	61
F3	57	M	R	Administrative assistant	135	CVA subcortical left	5 m	72
F4	59	M	R	Teacher polytechnic	161	CVA left temporal	4 m	72
F5	80	F	R	Housekeeper	117	CVA left	6 m	72
F6	71	M	R	Director building agency	141	iCVA right	11 y	72
F7	62	F	R	Office employee in factory	140	hCVA during resection meningioma left frontal, post-operative bifrontal iCVA	1 y 4 m	72
F8	45	M	R	Electrician	161	TIA's after dissection carotis interna left	1 y 9 m	72
F9	46	M	R	Military policeman	100	iCVA left	9 m	69.5
F10	41	F	R	Communication specialist	147	iCVA left temporal	6 y	70
F11	63	F	R	Tourist guide	207	Dissection abscess left temporoparietal	3 y	72
F12	65	M	R	Project leader in electricity	150	iCVA left temporofrontopariet al	1 y 6 m	72
F13	53	M	R	Teacher polytechnic	122	hCVA left frontotemporal	9 m	72
F14	83	M	R	Construction worker	149	iCVA left temporoparietal	5 y	71
F15	37	F	R	Financial administrator	106	iCVA left	2 y 2 m	72
F16	83	M	R	General director	102	iCVA left	2 y 3 m	69

B = agrammatic, F = fluent speaker, Hand = Handedness. Speech rate: number of words in two minutes divided by two. Utterances taken from answers to interview questions of the AAT (Graetz, De Bleser, & Willmes, 1992). iCVA: ischemic Cerebrovasculuar Infarct. ACM: artery cerebri media. Time post-onset (PO) y = year, m = months. BDAE: The score on 'Auditory Word Discrimination' of the Boston Diagnostic Aphasia Test (BDAE; Goodglass & Kaplan, 1972; Goodglass, Kaplan, & Baresi, 2001). Participants were asked to point at objects, geometrical forms, letters, actions, colours and numbers. The maximum score on this subtest was 72.

B.2 Verbs used in the Dutch aphasia test

Table B.2.2: Verb pairs with corresponding nouns used in the Dutch test.

Dutch verb	**Translated verb**	**Dutch noun**	**Translated noun**
Practice items			
lezen	*to read*	brief	*letter*
schrijven	*to write*	brief	*letter*
Experimental items			
drinken	*to drink*	melk	*milk*
inschenken	*to poor*	melk	*milk*
plakken	*to paste*	papiertje	*paper*
scheuren	*to tear*	papiertje	*paper*
tekenen	*to draw*	vierkant	*square*
schilderen	*to paint*	vierkant	*square*
strijken	*to iron*	trui	*sweater*
vouwen	*to fold*	trui	*sweater*
slijpen	*to sharpen*	potlood	*pencil*
breken	*to break*	potlood	*pencil*
naaien	*to sew*	lapje	*cloth*
breien	*to knit*	lapje	*cloth*
schillen	*to peel*	appel	*apple*
eten	*to eat*	appel	*apple*
trekken	*to pull*	kar	*cart*
duwen	*to push*	kar	*cart*
vullen	*to fill*	doos	*box*
legen	*to empty*	doos	*box*

B.3 Accuracy per Dutch aphasic participant

Table B.3.3: Individual accuracy scores, calculated over 18 items per condition.

	Simple past (%)	**Periphrastic past (%)**	**Simple present (%)**
Agrammatic aphasic speakers			
B1	44	6	78
B2	50	50	72
B3	50	83	89
B4	0	61	11
B5	33	0	78
B6	0	0	11
B7	0	6	17
B8	17	50	28
B9	6	28	56
B10	11	0	72
B11	6	11	39
B12	28	94	94
B13	0	22	33
B14	28	83	50
Mean	*19*	*35*	*52*
Fluent aphasic speakers			
F1	61	39	67
F2	0	6	33
F3	89	94	94
F4	83	100	100
F5	0	44	28
F6	44	17	83
F7	89	89	100
F8	83	94	100
F9	50	72	56
F10	56	94	100
F11	100	89	100
F12	17	83	94
F13	89	100	100
F14	0	6	89
F15	94	72	100
F16	33	50	67
Mean	*56*	*66*	*82*

C Appendix to chapter 5: Losing track of time? Incremental time reference processing

C.1 Individual German participant characteristics

Table C.1.1: Individual German participant characteristics.

Pp.	Age	Sex	Educ. years	H	Syndrome (severity)	MLU	Aetio-logy	Localisation	TPO [y;m]
Agrammatic aphasic participants									
B1	58	f	12	R	Broca (moderate)	3.8	SAH	left ACI	2;10
B2	41	f	13	R	Anomic* (mild)	4.69	iCVA	left ACM	12;6
B3	61	m	17	L	Broca (moderate)	3.42	hCVA	right temporo-parietal	18;1
B4	73	m	10	R	Broca (moderate)	2.07	iCVA	left ACM	15;0
B5	54	f	18	R	Broca (severe) with apraxia of speech	n.a.	hCVA, SAH	n.a.	4;6
B6	58	m	13	R	Broca (moderate-severe) with apraxia of speech	n.a.	iCVA	left ACM and ACI peri-/suprasylvian	1;0
Non-brain-damaged participants									
C1	45	m	10	R					
C2	38	f	19	R					
C3	43	f	13	R					
C4	66	f	12	R					
C5	62	m	16	R					
C6	64	f	16	R					
C7	69	f	13	R					
C8	38	f	17	R					
C9	77	m	17	R					
C10	67	f	14	R					
C11	66	m	21	R					
C12	61	f	15	R					

Pp. = Participant, Educ. = Education, H = handedness: R = right, L = left, TPO = Time post onset, y;m = years;months, SAH = subarachnoid hemorrhage, iCVA = ischemic cerebreovascular accident, hCVA = hemorrhaghic cerebrovascular accident, ACI = arteria carotis interna, ACM = arteria carotis media. *B2 was initially diagnosed as Broca's aphasic. Her spontaneous speech at the time of testing contained substitutions of plural with single nouns, omissions of determiners and verb forms and sometimes substitutions of finite verb forms with an infinitive, and she produced many incomplete utterances.

C.2 Verbs and nouns in the eye-tracking experiment

Table C.2.2: Verbs and nouns used in the eye-tracking experiment.

German verb	Translated verb	German noun	Translated noun
besprühen	to spray	Mauer	wall
blockieren	to block	Weg	road
dekorieren	to decorate	Zimmer	room
demontieren	to disassemble	Fahrrad	bike
entblößen	to bare	Schulter	shoulder
entfernen	to remove	Zecke	tick
entgräten	to filet	Fisch	fish
enthäuten	to peel	Zwiebel	onion
entkorken	to uncork	Flasche	bottle
entsaften	to juice	Orange	orange
entsteinen	to remove the stone	Kirsche	cherry
entwirren	to disentangle	Seil	rope
entzünden	to light	Kerze	candle
gravieren	to engrave	Ring	ring
lackieren	to polish	Nagel	nail
rasieren	to shave	Bein	leg
sortieren	to sort	Sammlung	collection
verbeulen	to bump	Auto	car
verbuddeln	to bury	Dose	can
verschmutzen	to soil/dirty	Tischtuch	table cloth

C.3 Accuracy and RT per German aphasic participant

Table C.3.3: Accuracy and response time per German aphasic participant.

	Eye-tracking experiment				**TART**		
Parti-	Accuracy (%)		Reaction time [ms] correct		Accuracy (%)		
cipant	Future	Past	Future	Past	Future	Present	Past
B1	70	90	3623	3833	80	80	80
B2	95	95	2556	2485	90	95	95
B3	80	90	5190	3550	75	100	70
B4	65	95	3550	3321	85	90	80
B5	20	85	6634	3990	65	90	30
B6	50	95	4191	3067	70	90	95
Mean	64	92	*3907*	*3349*	*75*	*91*	*78*

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Summary

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 LInking 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.

Samenvatting

Verworven hersenletsel, bijvoorbeeld als gevolg van een beroerte, kan leiden tot de taalstoornis *afasie*. Afasie kan zich op veel verschillende manieren openbaren, bijvoorbeeld door grammaticale problemen bij *agrammatische afasie* of door woordvindingsproblemen bij *vloeiende afasie*. Opvallend is dat voor vrijwel alle mensen met afasie werkwoorden erg lastig zijn, terwijl die werkwoorden nou juist zo belangrijk zijn in onze communicatie. Dit proefschrift gaat in op een oorzaak van die problemen met werkwoorden, namelijk tijdsverwijzing. Het blijkt namelijk zo te zijn dat werkwoorden die naar het verleden verwijzen (zoals 'hij liep') moeilijker zijn dan werkwoorden die naar het heden of de toekomst of een ongespecificeerde tijd verwijzen. Dit is vooral duidelijk naar voren gekomen bij mensen die agrammatische afasie hebben.

In dit proefschrift worden verschillende onderzoeken beschreven naar tijdsverwijzing van werkwoorden. De onderzoeken zijn uitgevoerd bij afatische en gezonde sprekers van het Nederlands, Duits, en Russisch. De rode lijn van het proefschrift vormt de *PAst DIscourse LInking Hypothesis* (PADILIH), opgesteld door Bastiaanse en collega's (2011). Volgens deze hypothese is verwijzing naar het verleden moeilijker dan verwijzing naar het heden, omdat er dan naar een activiteit vóór het moment van spreken verwezen wordt. Die gebeurtenis moet daarom uit de context worden opgeroepen. Dit oproepen wordt een *discourse-link* genoemd, en kost extra hersencapaciteit. Deze discourse-link is niet nodig (of mogelijk) voor acties in de toekomst, omdat die nog niet gebeurd zijn.

Eén van de vragen binnen de neurolinguïstiek (de studie naar taal in de hersens) is of moeilijkheden met bepaalde taalconstructies bij afasie een gevolg zijn van het uitvallen van een hersenengebied door letsel. Het kan namelijk zo zijn dat ook gezonde mensen deze constructies moeilijker vinden. Echter, omdat hun hersens verder goed functioneren, worden die moeilijkheden in het dagelijks leven niet opgemerkt. Hun hersens hebben genoeg rekenkracht om die moeilijke taalconstructies snel en nauwkeurig te begrijpen en uiten.

In de introductie in *Hoofdstuk 1* wordt uitgelegd dat er methodes bestaan om het brein van gezonde mensen in werking te bestuderen, bijvoorbeeld door hersenmetingen met behulp van *elektro-encefalografie* (EEG). Bij die techniek worden elektrodes op de hoofdhuid geplakt, die de zwakke elektrische signalen meten die de hersencellen produceren wanneer ze aan het werk zijn. De reacties van hersenen tijdens het lezen van zinnen kunnen daarmee aan verschillende taalkundige processen gerelateerd worden, waaronder bijvoorbeeld de grammaticale verwerking. Een andere techniek waarmee hersenprocessen goed kunnen worden bestudeerd is het meten van *oogbewegingen*. Wanneer mensen een zin horen, kijken ze namelijk vrijwel gelijktijdig naar objecten die geassocieerd worden met wat er gezegd wordt. Door de oogbewegingen naar verschillende objecten op een beeldscherm te volgen, kunnen conclusies getrokken worden over hoe mensen een bepaalde zin verwerken.

In *Hoofdstuk 1* staat meer achtergrondinformatie over afasie, tijdsverwijzing en de gebruikte onderzoeksmethodes beschreven. Vervolgens worden kwesties naar aanleiding van de volgende onderzoeksvragen aangekaart:

1. Zijn werkwoorden die naar het verleden verwijzen lastig voor mensen met afasie doordat er een discourse-link nodig is? Als dit zo is, zou een discourse-link voor verwijzing naar het verleden vergelijkbare problemen moeten opleveren als andere taalstructuren waarvoor een discourse-link nodig is.

2. Is de PADILIH van toepassing op taalverwerking in het algemeen? De hypothese was opgesteld op basis van de problemen die mensen met agrammatische afasie ondervinden, maar bij andere afasievormen en gezonde mensen kost verwijzing naar het verleden wellicht ook extra moeite in vergelijking met verwijzing naar het heden of de toekomst.

3. Geldt de PADILIH voor tijdsverwijzing onafhankelijk van de werkwoordstijd? In het Nederlands kan namelijk met zowel de onvoltooid *verleden* tijd (bijvoorbeeld ‘hij liep’) als met de voltooid *tegenwoordige* tijd (bijvoorbeeld ‘hij heeft gelopen’) naar het verleden worden verwezen.

4. Hoe en wanneer interpreteren mensen met agrammatische afasie tijdsverwijzing van werkwoorden in vergelijking met gezonde mensen? De

moeilijkheden van verwijzing naar het verleden zorgen wellicht voor afwijkingen of vertragingen. Bovendien is het niet duidelijk wat er misgaat wanneer de tijdsverwijzing van de werkwoordsvorm verkeerd wordt geïnterpreteerd.

In *Hoofdstuk 2* wordt een begripsstudie beschreven waaraan twee groepen Russische mensen met afasie, namelijk agrammatische en vloeiende afasie, hebben deelgenomen. In deze studie werden drie taalstructuren onderzocht waarvoor een discourse-link nodig is, waaronder werkwoorden die verwijzen naar het verleden. Beide groepen bleken moeite te hebben met deze structuren, wat in lijn is met de PADILIH. Bovendien blijkt hieruit dat de noodzaak tot het maken van een discourse-link niet alleen bij agrammatisch afatische mensen tot problemen leidt.

In *Hoofdstuk 3* wordt een test beschreven die bij Nederlandstalige mensen met agrammatische en vloeiende afasie is afgenomen. Deze studie bewijst dat problemen met verledentijdsverwijzing die mensen met afasie hebben, onafhankelijk zijn van problemen die zuiver met werkwoordsverbuigingen te maken hebben. Het was voor beide groepen namelijk moeilijker om zinnen af te maken met werkwoorden in voltooid *tegenwoordige* tijd (bijvoorbeeld 'heeft gedweild') en in onvoltooid *verleden* tijd (bijvoorbeeld 'dweilde'), dan met werkwoorden in onvoltooid *tegenwoordige* tijd (bijvoorbeeld 'dweilt'). De mensen met vloeiende afasie maakten echter andere fouten: Ze gebruikten een andere werkwoordsvorm dan gevraagd, maar verwezen wel naar de juiste tijd. Als mensen met agrammatische afasie naar het verleden moesten verwijzen, deden ze dat in de meerderheid van de testzinnen echter niet.

In *Hoofdstuk 4* wordt een EEG-studie beschreven waarin ook bij gezonde mensen de effecten die veroorzaakt worden door de werkwoordstijd worden losgekoppeld van effecten die veroorzaakt worden door verwijzing naar het verleden. De PADILIH werd al ondersteund door eerdere EEG-studies met werkwoorden die naar het heden of verleden verwijzen. Bij deze studies werd de voltooid tegenwoordige tijd (bijvoorbeeld 'heeft geschaatst') echter niet gebruikt voor verwijzing naar het verleden, alleen de onvoltooid verleden tijd (bijvoorbeeld 'schaatste'). De studie van *Hoofdstuk 4* toont aan dat de PADILIH ook op gezonde mensen van toepassing is én onafhankelijk is van werkwoordstijd.

In *Hoofdstuk 5* wordt een Duitse studie met agrammatisch afatische en gezonde proefpersonen beschreven waarin de oogbewegingen tijdens het luisteren naar zinnen werden onderzocht. De zinnen bevatten werkwoorden in de voltooid tegenwoordige tijd of de toekomende tijd. Er werden steeds twee plaatjes getoond: een van het omschreven object in de staat vóór de handeling, en een in de staat na de handeling van het werkwoord. De proefpersonen moesten steeds het juiste plaatje kiezen. De resultaten waren in overeenstemming met de PADILIH: De oogbewegingen lieten zien dat agrammatisch afatische proefpersonen de werkwoordsvorm die naar de toekomst verwees even snel verwerkten als de gezonde proefpersonen, maar de werkwoordsvorm die naar het verleden verwees minder snel.

In *Hoofdstuk 6* van het proefschrift worden de conclusies samengevat met betrekking tot de kwesties uit *Hoofdstuk 1* en worden implicaties en richtingen voor vervolgonderzoek aangegeven. De status van verwijzing naar de toekomst behoeft bijvoorbeeld meer aandacht. Verder zijn werkwoorden een belangrijke focus van afasietherapie. De kennis van dit proefschrift kan bijdragen aan de interpretatie van afasietesten en het ontwikkelen van nieuwe therapiematerialen. Voor communicatie is begrijpelijke en informatieve taal belangrijk. Het trainen van werkwoorden die naar het verleden verwijzen heeft wellicht niet de hoogste prioriteit voor afasietherapie. De diversiteit aan werkwoorden (die de juiste betekenis dragen) zou daarentegen meer aandacht moeten krijgen dan de werkwoordstijden.

About the author

Laura Simone Bos was born on November 3rd, 1983 in Alkmaar (NL), where she attended grammar school. She started her propaedeutic studies in Linguistics in 2004 at the University of Leiden. A strong interest in neurolinguistics made her continue her undergraduate studies at the University of Groningen, with an exchange semester at the University of Toulouse II *Le Mirail* (FR). She obtained both her Bachelor degree in Linguistics and a propaedeutic in Romance Languages in 2008. She was then admitted to the European Master in Clinical Linguistics (EMCL), part of the *Erasmus Mundus Excellence Program*, for which she spent semesters in Milan (IT), Potsdam (DE), and Groningen (NL). In 2010 she acquired her MSc title with overall classification *excellent* based on her thesis *Time reference in non-brain-damaged and agrammatic speakers of Dutch.* During and after her master studies, she worked as a teaching- and research assistant at the University of Groningen (NL). Later in 2010 she started a fully-funded 4-year PhD project there, and in 2011 she was admitted to the joint Erasmus Mundus PhD Program *International Doctorate for Experimental Approaches to Language And Brain (IDEALAB)* of the Universities of Groningen (NL), Newcastle (UK), Potsdam (DE) and Trento (IT), and Macquarie University, Sydney, (AU). She received training in Trento, Sydney, Groningen, and Potsdam and carried out research at the University of Groningen (NL), at the Center for Speech Pathology and Neurorehabilitation, Moscow (RU), and at the University of Potsdam (DE). For the latter, she was awarded a one-year scholarship from the Collaborative Research Center *SFB 632* of the German Research Foundation (DFG).

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Laura Simone Bos is op 3 november 1983 geboren te Alkmaar (NL), waar ze naar het gymnasium ging. Ze begon aan haar propedeuse Taalwetenschap aan de Universiteit Leiden in 2004. Vanwege een sterke interesse in de neurolinguïstiek zette ze haar studie voort aan de Rijksuniversiteit Groningen, met een semester aan de Universiteit van Toulouse II *Le Mirail* (FR). In 2008 ronde ze haar bachelor Taalwetenschap en een propedeuse Romaanse Talen en Culturen af. Ze werd toen toegelaten tot de *European Master in Clinical Linguistics (EMCL)*, onderdeel van het *Erasmus Mundus Excellence Program*, waarvoor ze semesters in Milaan (IT), Potsdam (DE) en Groningen (NL) studeerde. In 2010 behaalde ze haar MSc-titel *cum laude* met haar scriptie *Time reference in non-brain-damaged and agrammatic speakers of Dutch.* Tijdens en na haar masterstudie werkte ze als onderwijs- en onderzoeksassistent aan de Rijksuniversiteit Groningen. Later in 2010 begon ze daar aan een volledig gefinancierd PhD-project, en in 2011 werd ze toegelaten tot het gezamenlijke Erasmus Mundus PhD-programma *International Doctorate for Experimental Approaches to Language And Brain (IDEALAB)* van de Rijsuniversiteit Groningen, de Universiteiten van Newcastle (UK), Potsdam (DE) en Trento (IT), en Macquarie University (AU). Ze is onderwezen in Trento, Sydney, Groningen en Potsdam en heeft buiten Groningen onderzoek gedaan aan het Center for Speech Pathology and Neurorehabilitation in Moskou (RU), en de Universiteit van Potsdam (DE). Voor haar onderzoeksverblijf in Duitsland heeft ze een eenjarige studiebeurs geworven van het gezamenlijke onderzoekscentrum *SFB 632* van de Duitse Onderzoeksorganisatie (DFG).

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