

University of Groningen

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

Bos, Laura

**IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.**

*Document Version*

Publisher's PDF, also known as Version of record

*Publication date:*

2015

[Link to publication in University of Groningen/UMCG research database](#)

*Citation for published version (APA):*

Bos, L. (2015). *The brain, verbs, and the past: Neurolinguistic studies on time reference*. [Thesis fully internal (DIV), University of Groningen, Univ Potsdam, University of Potsdam, Macquarie University]. [S.n.].

### Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

### Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

# 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 sys-

---

tem 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-mnemonic aphasia* is translatable into anomic aphasia. The sixth syndrome Luria described is *acoustic-mnemonic 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
<i>Boston</i>	<i>Luria</i>				
Broca’s	Efferent motor	-	+	-	Telegraphic speech
Transc. motor	Dynamic	-	+	+	Relatively spared repetition
Global		-	-	-	All modalities disturbed
Wernicke’s	Sensory	+	-	-	Paraphasias
	Acoustic-mnemonic	+	-	-	Impaired verbal memory, anomia
Anomic	Semantic-mnemonic	+	+	+	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<sup>th</sup> 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 even-

tual 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.<sup>1</sup> Likewise, a personal pronoun refers to a specific discourse element, for example in *The man<sub>i</sub> shaves [him<sub>j</sub>]*, where *him* links to someone identified in discourse structure. Making such a discourse link is not needed for *The man<sub>i</sub> shaves [himself<sub>i</sub>]*, 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.

---

<sup>1</sup>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<sup>2</sup> (Zagona, 2013) and is neither discourse-linked nor bound.<sup>3</sup> 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	[has <sub>present tense</sub>	written	]reference to the past
Dutch:	hij	[heeft <sub>present tense</sub>	geschreven	]reference to the past
German:	er	[hat <sub>present tense</sub>	geschrieben	]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.

---

<sup>2</sup>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’.

<sup>3</sup>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.

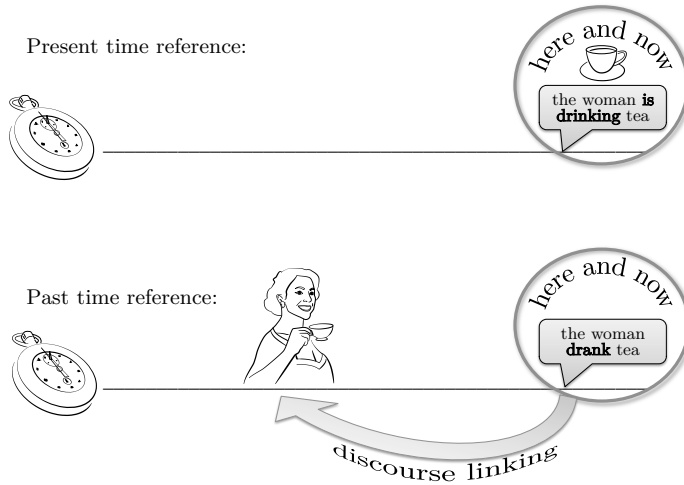


Figure 1.1: Schematic illustration of the PADILIH. The upper time line illustrates present time reference in the sentence *the woman is drinking tea*. For present time reference, no discourse-linking is needed: The sentence can be interpreted in the here and now of the moment of speaking. The lower time 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](http://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 (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 past 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 Rus-



sian 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 disserta-

tion. It addresses the four main issues raised in the previous section. The implications and proposed directions for further studies are then discussed.

