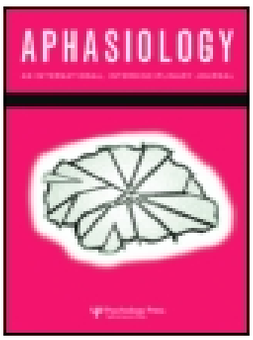

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Processing of time reference in agrammatic speakers of Akan: a language with grammatical tone

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ABSTRACT

Background: Languages of the world have several ways of expressing time reference. Many languages such as those in the Indo-European group express time reference through tense. Languages such as Chinese and Standard Indonesian express time reference through aspectual adverbs, while Akan does so through grammatical tone. Previous studies have found that time reference is selectively impaired, with reference to the past being more impaired than reference to the non-past. The PAst DIscourse LInking Hypothesis (PADILIH) posits that pastime reference is difficult because it requires discourse linking.

Aims: The goal of this study was first to examine whether pastime reference is impaired also in languages that do not use grammatical affixes but rather tone, to make time reference. Second, this study aims to decouple the effect of tone from the effect of temporal reference on Akan verbs.

Method and Procedures: Ten Akan agrammatic speakers and 10 non-brain-damaged speakers (NBDs) participated in this study. An Akan adapted version of the Test for Assessing Reference of Time (African TART), for both production and comprehension was used. The TART focuses on the future, present (habitual) and the pastime frames. Additionally, five of the agrammatic speakers performed two tonal discrimination tasks: a non-linguistic and a linguistic (lexical) one.

Outcomes and Results: While the NBDs scored at ceiling, the agrammatic speakers made errors, and these affected past more than present and the future time references, in both comprehension and production tasks. However, the comprehension data showed a dissociation between the present habitual and the future. The substitution error analysis revealed a preference for the present. The five agrammatic speakers showed an intact performance on non-linguistic tonal discrimination task.

Conclusion: The conclusion is that regardless of how time reference is expressed, whether through inflectional morphology or grammatical

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tone, reference to the past is problematic for individuals with agrammatic aphasia. The fact that the agrammatic speakers could perceive the non-linguistic tonal differences demonstrates that it is not tone in general that is disrupted, but rather time reference, particularly reference to the past, as predicted by the PADILIH.

Introduction

Languages around the world have several ways of expressing time reference. Many languages such as those in the Indo-European group express time reference through tense (Reichenbach, 1947; Comrie, 1976; and many others). Many Asian languages, such as Chinese and Standard Indonesian, express time reference through aspectual adverbs (Grangé, 2003, 2006; Smith & Erbaugh, 2005), while Akan, a language in the Niger–Congo family, does so through grammatical tone (Dolphyne, 1988). Recent studies have demonstrated that time reference, particularly reference to the past is impaired in individuals with agrammatic aphasia, while reference to the non-past (present and future time reference) is relatively spared (Abuom & Bastiaanse, 2012; Bastiaanse, 2008, 2013; Bastiaanse et al., 2011; Bos & Bastiaanse, 2014; Dragoy & Bastiaanse, 2013; Martínez-Ferreiro & Bastiaanse, 2013). The PAst DIscourse LInking Hypothesis (PADILIH: Bastiaanse et al., 2011) posits that pastime reference is difficult because it requires discourse linking, whereas for reference to the non-past (present and future) no discourse-linking is needed (see next section for further details about the PADILIH). The issue of time reference has been extensively studied in languages that use inflectional verb morphology[1] for time reference, but there are little data on languages that do not. Thus, it remains unclear whether the impairment in past reference reflects a combined selective deficit in time reference and grammatical morphology or a selective deficit in time reference only.

The current study investigates the ability of individuals with agrammatic aphasia to refer to different time frames and to process/comprehend time reference in Akan, a language that expresses time reference by grammatical tone, rather than tense. The question is whether time reference difficulties, particularly reference to the past in agrammatism are restricted only to languages that use verb morphology (such as tense), or whether the impairment can be extended to tonal languages that use grammatical tone to express time reference, such as Akan.

Tense, aspect, time reference, and the PADILIH

Comrie (1985) defines Tense as the "grammaticalised expression of location in time". That is, tense is a grammatical category that conveys information about the time in which an event takes place, usually relating the event time to the speaking time. While Tense is a grammatical category, Time Reference is a semantic category that is closely related to Tense. Similarly to tense, Aspect is a semantic category, in many languages grammaticalized and encoded in the verb, that describes the internal temporal constituency of an event by indicating whether it is completed (perfective aspect), ongoing (imperfective aspect) or repetitive (imperfective aspect) (Comrie, 1976). Many studies on aphasia have shown that the processing of tense, which indicate the time reference of an event, are

problematic. (Bastiaanse, 2008; Burchert, Swoboda-Moll, & De Bleser, 2005; Friedmann & Grodzinsky, 1997; Gavarró & Martínez-Ferreiro, 2007; Nanousi, Masterson, Druks, & Atkinson, 2006; Wenzlaff & Clahsen, 2004, 2005). Further, recent studies have demonstrated that not all time frames are equally impaired in agrammatism, and that reference to the past is more susceptible to being impaired than reference to the present and the future. Interestingly, it is not just past tense that is difficult but rather reference to the past. In Dutch (and German), reference to the past can be done both by past tense (in combination with perfect or imperfect aspect) and by present perfect. Here, perfect aspect denotes that the event took place in the past, even though the finite verb (auxiliary) is in present tense. Production of the present perfect is impaired in Dutch agrammatic speakers (Bos & Bastiaanse, 2014). Apparently, an event that has been completed is difficult to express through verb inflection: perfect is impaired in Dutch agrammatic speakers, even though the finite verb is in present tense.

According to Avrutin (2000, 2006), the processing of tense requires access to "discourse syntax", where a link has to be made between the sentence and the discourse, unlike subject-verb agreement which requires only an intra-sentential linkage (resolved within "narrow syntax") to process. Avrutin claims that problems with tense should be more often observed than problems with subject-verb agreement in the speech of patients with Broca's aphasia because discourse linking (extra sentential processing) requires more processing resources than narrow syntax (intra-sentential processing). Zagona (2003) makes it even more specific, and suggests that it is not tense per se that is discourse linked but verb tense that makes reference to the past. According to Zagona (2003), present verb tense is bound locally (intra-sententially) because the time of the event and speech time coincide, and thus, present tense is not discourse linked. Future time reference is categorized as a subclass of present tense; hence, it is not discourse linked either (Zagona, 2013). Therefore, only past tense needs to be discourse linked.

Building on the ideas of Zagona (2003) and Avrutin (2000, 2006), Bastiaanse et al. (2011) and Bastiaanse (2013) formulated the PADILIH, which claims that pastime reference, whether expressed through tense and/or aspectual verb inflection, is selectively impaired because it has to be linked to the discourse. That is, reference to the past through free and bound grammatical morphemes, including periphrastic verb forms denoting perfect aspect that refer to a completed action (in Dutch *heeft gelezen*: lit. "has walked") is impaired. According to the PADILIH, when referring to the past, the time of speaking does not coincide with the event time; hence, a link between these two different time points has to be established. However, reference to the present requires that the time of speaking coincides with the time of the event, and hence, no discourse linking is required. In reference to the future, although the time of speaking and event time do not coincide, there is no discourse linking since the event has not yet taken place. Additionally, future reference is not bound within the sentence nor to the discourse. Bastiaanse (2013) follows Zagona (2013) and suggests that both the present and the future time reference could be paired as "non-past", and thus, are assumed to be less costly.

The PADILIH accounts for the selective impairment of pastime reference which has been found in many studies on aphasia across different clinical populations and languages (English and Turkish: Bastiaanse et al., 2011; Russian: Dragoy & Bastiaanse, 2013;

Dutch: Bos & Bastiaanse, 2014; Bastiaanse, 2008; Spanish: Martínez-Ferreiro & Bastiaanse, 2013; Korean: Lee, Kwon, Na, Bastiaanse, & Thompson, 2013). The predictions of the PADILIH are supported not only by evidence from monolingual aphasia but also by production and comprehension data from bilingual agrammatic aphasia. For instance, whenever the bilingual agrammatic speakers reported by Abuom and Bastiaanse (2013) and Abuom, Obler, and Bastiaanse (2011) made time reference errors, past reference was most affected, whereas present and future reference was relatively intact. Importantly, this pattern emerged in both languages of the agrammatic participants, despite the fact that they vastly differed morphologically. Recently, some studies have shown that the selective impairment of pastime reference, as claimed by the PADILIH, is not restricted to agrammatic aphasia, but also extends to fluent aphasias (Bos & Bastiaanse, 2014; Dragoy & Bastiaanse, 2013). Interestingly, the PADILIH also accounts for the selective impairment in the use of past and non-past in patients with Alzheimer's disease (AD) and semantic dementia (SD): Irish et al. (2016) examined the use of past and present tenses in auto-biographical narratives in patients with AD and SD, and found that verbs referring to the past were significantly compromised in both groups, as compared to the healthy speakers. Further, the cross-linguistic (Greek and Italian) individual data from speakers with AD showed a worse performance on past reference than on future reference (Fyndanis et al., 2018b), which is consistent with the PADILIH.

However, some studies have demonstrated conflicting results on the present and the future time reference. Martínez-Ferreiro and Bastiaanse (2013) found that Spanish and Catalan individuals with non-fluent aphasia show a dissociation between the present and the future, with the present being better preserved, in comprehension. Nonetheless, such difference was not replicated in production. The asymmetry between the future and the present habitual has also been found in Greek-speaking agrammatic individuals, who showed a significantly better performance in simple present than simple future in Greek (Nanousi et al., 2006). Faroqi-Shah and Friedman (2015) and Fyndanis et al. (2018a) also challenge the validity of the PADILIH. Fyndanis et al. (2018a) reported that, at the group level, Greek-speaking and Italian-speaking individuals with agrammatic aphasia were equally impaired in past and future reference, whereas Faroqi-Shah and Friedman (2015) did not find any consistent differences between present, past and future tense.

The PADILIH has also been tested in languages that do not use verb inflection but rather free-standing aspectual adverbs for time reference, such as Chinese and Standard Indonesian (Chinese: Bastiaanse et al., 2011; Standard Indonesian: Anjarningsih & Bastiaanse, 2011). In these languages, the aspectual adverbs are optional and are only used when the time frame of the event is not clear from the context. Therefore, whether an event is completed or not depends on the internal temporal constituency of the event; and this piece of information is not discourse-linked, because aspectual information is non-deictic (Comrie, 1976). This is supported by the data: both in Chinese and in Standard Indonesian, reference to past, present and future is equally impaired in agrammatic production (Bastiaanse, 2013).

In this section, it has been explained that time reference is problematic when discourse linking is required. Nonetheless, depending on the structure of a language, and the linguistic means by which time reference is expressed, different time frames may be affected. The section that follows describes the structure of Akan, particularly grammatical tone.

Linguistic background of Akan

Akan is a language spoken in sub-Saharan Africa, particularly Ghana, as well as in the eastern part of Cote d'Ivoire. Akan belongs to the Kwa group of the Niger–Congo language family. There are three main dialects of Akan, namely: Asante Twi, Akwuapim Twi, and Fante. All the three dialects are mutually intelligible. The Akan dialect under study is the Asante Twi, the most widely spoken dialect. About 48% of Ghana's population of 24 million are native speakers of Akan (Ghana Statistical Service, 2013). Nonetheless, an overall estimate of 80% of Ghanaians speak Akan as either the first or second language. A form of Akan is also spoken in some parts of the Caribbean, notably Suriname and Jamaica, as a result of the trans-Atlantic trade. In Ghana, the educational policy requires that a child can use his/her native language as the medium of instruction and communication until Grade 3 (Mfum-Mensah, 2005). Although English is the official language in Ghana, Akan is the most dominant language used in the media, trade, religion, political campaigns, and day-to-day interaction among people. Linguistically, Akan has some distinctive features such as tone, vowel harmony, nasalization, and the phenomenon of serialization. The base word order of Akan is Subject Verb Object (SVO).

Akan is a tonal language. This entails that the meaning of a sentence in Akan depends not only on the vowels and the consonants that make up the words but also on the relative pitch with which each syllable of the sentence is produced (Dolphyne, 1988; Osam, 2003, 2008). Akan has two basic tones: High tone (H) and Low tone (L), and they are pronounced on a relatively level pitch[2] (Abakah, 2000, 2005; Dolphyne, 1988). In Akan, tone has both lexical and grammatical functions.

Lexical tone:

(1a)	Pàpá'	father'
(1b)	Pàpà'	fan'
(1c)	Pápá'	good'

Grammatical tone:

(2a)	*Peter*	*gyìná*	*hɔ*
	Peter	stand-HAB	there.
Peter stands there.			
(2b)	*Peter*	*gyìnàà*	*hɔ*
	Peter	stand-PAST	there.
Peter stood there.			
(2c)	*Peter*	*bégyíná*	*hɔ*
	Peter	FUT-stand	there.
	Peter stands there.		

In the Akan examples from (1a–1c), the meaning of the word *"papa"* changes depending on the tonal pattern of the vowels. Similarly, in the grammatical tone examples (2a–2c), the same verb "-gyina-" (meaning "stand") is perceived as either habitual aspect as in (2a) or past tense in (2b) depending on the tone on the syllabic units of the verb. That is, the difference between the habitual and the past is indicated solely by tone and duration. Whereas the tonal pattern on the disyllabic verb for the habitual aspect in (2a) is Low – High, the past has a Low-Low tonal pattern, with a prolonged tone on the last syllable, as in (2b). In the case of

monosyllabic verbs, the tone of the habitual aspect is always High. In (2c), which is the Akan future, the verb has to be prefixed by the morpheme *bɛ́-/bé* with a high tone. The future verb form is marked by a High-High-High tone pattern in (2c).

The Akan past and the habitual time frames are semantically distinctive. According to Boadi (2008), it is inappropriate to refer to the marker (tone) of the Akan habitual as present tense (since it does not locate events in time) although it is used to express present time and/or any indefinite time. Nonetheless, Boadi (2008) refers to the habitual as the "Present habitual" since it semantically connotes the idea of present time rather than past. In sum, the Akan habitual always expresses a non-past time. Therefore, we refer to the Akan habitual aspect as "present habitual".

Tone processing in aphasia

Although there are about 1000 estimated tonal languages in Africa (Fromkin & Rodman, 1993), studies on tone processing in aphasia have predominantly focused on Thai, Chinese and Norwegian (Gandour, Ponglorpisit, & Dardarananda, 1992a; Liang & Heuven, 2004; Moen, 2009; Van Lanker, 1980; Yiu & Fok, 1995). Studies on non-brain-damaged individuals have shown that acoustic processing, such as processing of pitch, predominantly involves the right hemisphere whereas the processing of phonological information, including linguistic tone, is more left lateralized (Friederici & Alter, 2004; Wong, 2002; Zatorre, Belin, & Penhune, 2002). Most of these studies, if not all, have focused on perception and/or production of lexical tone, and have demonstrated that tone language speakers with aphasia show substantial impairment in lexical tone processing (Gandour, Petty, & Dardarananda, 1988; Kadyamusuma, De Bleser, & Mayer, 2011).

Yiu and Fok (1995) demonstrated that Cantonese tone processing is disrupted in individuals with aphasia while it is intact in dysarthric patients; hence, the tone processing deficit could be attributed to the lesion sites (especially in the left hemisphere) that result in aphasia. They also reported that Cantonese aphasic speakers produce more tonal errors than consonant or vowel errors. This is consistent with the findings of Liang and Heuven (2004), who examined the speech of a female Mandarin-speaking individual with Broca's aphasia and found that her production of lexical tones was more disrupted than production of vowels. Based on their findings, Liang and Heuven (2004) suggested a separate function and localization for segmental and tonal aspects of lexical entries in tonal languages. Additionally, Gandour et al. (1992a) reported that Thai speakers with nonfluent aphasia show a higher error rate in both perception and production of lexical tone in Thai. Kadyamusuma et al. (2011) investigated the ability of aphasic individuals with left hemisphere damage to identify lexical tone in Shona, a Bantu language spoken in Zimbabwe. In Kadyamusuma et al.'s (2011) study, the Shona-speaking participants with aphasia were found to be impaired in lexical tone perception. The disruptions shown in lexical tone processing in Shona, an African language, are consistent with previous findings in other tone languages such as Chinese and Thai (Gandour & Dardarananda, 1984; Yiu & Fok, 1995).

Furthermore, Gandour et al., (1992a, 1992b) demonstrated that tonal duration is relatively intact in Thai nonfluent aphasia. Thai tones vary in terms of duration, with the falling tone and the mid tone being the shortest and the longest tones, respectively. Gandour and colleagues found that Thai speakers with nonfluent aphasia have a preserved ability to

control relative differences in tone duration associated with the Thai phonological contrast in vowel length (Gandour & Dardarananda, 1984; Gandour et al., 1992a, 1992b).

In summary, there is cross-linguistic evidence that patients with left hemisphere brain damage, particularly patients with nonfluent aphasia in Chinese (Yiu & Fok, 1995), Thai (Gandour et al., 1992a, 1992b), and Shona (Kadyamusuma et al., 2011), show a disruption in perception and production of lexical tone, with tonal duration being relatively intact. However, all the studies on tone processing in aphasia have explored lexical tone, leaving grammatical tone an untapped research area.

Goals of the present study

This study had two goals. The first goal was to find out whether the observed differences in past versus non-past (present and future) time reference are restricted to languages with morphological verb inflections, or whether they are also manifest in languages that express time reference through grammatical tone. The distinctive realization of the Akan present habitual aspect and the simple past, that are only different in tone and vowel duration, makes it a very suitable language to address this question. According to the predictions of the PADILIH, Akan speakers with agrammatic aphasia should have difficulty with reference to the past, although there is no verb inflection, since the deficit is claimed to affect discourse linking and not tense marking.

The second goal of this study was to investigate whether the presence of tense morphology (coupled with tone) makes the Akan future verb form more difficult than the present habitual verb form, which is marked solely by tone. According to Zagona (2013), future time reference is categorized as a subclass of present tense, hence not discourse linked. Therefore, the PADILIH predicts that both the future and the present time frames should be relatively spared (Bastiaanse, 2013). If the involvement of verb morphology negatively impacts the performance of individuals with agrammatic aphasia on tasks tapping into time reference; then, Akan future time reference should be more difficult in both comprehension and production than reference to the present, which does not require inflectional morphology.

To address these goals, the current study used the Akan version of the Test for Assessing Reference of Time (TART: Bastiaanse, 2008; African TART: Abuom & Bastiaanse, 2010).

Materials and method

Participants

The current study involved two participant groups: Ten individuals with agrammatic aphasia, and 10 non-brain-damaged (NBD) participants. The aphasia group consisted of seven males and three females, with a mean age of 53.9 (range: 19–76, SD = 16.9) years, while the NBD group consisted of 5 males and 5 females with a mean age of 51 (range: 35–71, SD = 11.5) years. Each participant in either of the groups had had at least 9 years of education formal education (Aphasia group: range = 10–16 years, mean = 13.3, sd = 2.49; NBD: range = 9–16 years, mean = 13.1, sd = 3.25). A two sample t-test showed no significant difference in years of formal education between the two groups ($t = 0.1544$, $df = 16.89$, $p = 0.88$). All participants spoke Akan as their native language and had been

using Akan as their primary language since birth. All agrammatic speakers were recruited from the Speech and Language Therapy Centre, as well as the Physiotherapy Center, Korle Bu Teaching Hospital, Ghana. The presence of aphasia was established by a consensus between a Speech and Language Therapist and a neurolinguist.

All agrammatic speakers were right-handed premorbidly and reported having no history of neurological diseases or developmental speech and/or language disorders. No vision or hearing problems were present in any of the patients. Data from computerized tomographic (CT) scans showed that all patients had suffered from a single stroke in the left hemisphere. The time post-onset of stroke ranged from 7 to 36 months (see Appendix A1 for all demographic data). The study was approved by the boards of the Research Ethical Review Committee (CETO) of the Faculties of Arts, Philosophy, and Theology and Religious Studies, University of Groningen, and the Korle Bu Teaching Hospital-Institutional Review Board (KBTH-IRB), Accra, Ghana. All participants gave their written informed consent.

Since there are no standardized tests for diagnosing aphasia syndromes in Ghana, the presence of agrammatic aphasia was diagnosed on the basis of the analysis of spontaneous speech samples, following the methods of Bastiaanse and Jonkers (1998). Spontaneous speech sample was elicited by questions on the history of stroke, how the participant spends their day and about their previous work. The speech sample from each participant was analyzed, and all agrammatic speakers showed reduced speech rate, Mean Length of Utterance (MLU) and produced more grammatical errors as compared to the NBDs (see Appendix A2 for the results of the spontaneous speech analysis). An Akan adapted version of the auditory word comprehension (nouns, verbs, letters, and numbers) subtest of the *Boston Diagnostic Aphasia Examination* (BDAE: Goodglass & Kaplan, 1972) was also administered to test the agrammatic speakers' auditory single word comprehension abilities. The agrammatic speakers' scores on the BDAE are reported in Appendix A2. The word "hammock" in the nouns subtest was not included in the Akan adapted version because it is not culturally appropriate for usage in Akan. All speakers with agrammatic aphasia showed a good single word comprehension and nonfluent speech.

Materials and procedures

Pretests for tone discrimination abilities

Because grammatical tone perception is crucial in distinguishing between Akan past and present habitual, five[3] of the agrammatic speakers performed a Tonal Screening Test (TST: Bruder et al., 2011; Bruder, Wexler, Sage, Gil, & Gorman, 2004; Kayser, 2011; Stevens, Donegan, Anderson, Goldman-Rakic, & Wexler, 2000; Wexler, Stevens, Bowers, Sernyak, & Goldman-Rakic, 1998), in which a pair of non-linguistic tones is judged to be either the same or different. The tones were made up of 300-ms sine waves with frequencies between 325 and 1994 Hz. There was 100 ms silence between each tonal pair. The TST had 70 tonal pairs in total: 10 practice items, and 60 main trials. The test included a 30-s break after every 20 trials. The purpose of this task was to ensure that the patients' ability to perceive non-linguistic tone was intact. Therefore, any errors (if any) made on the linguistic tone task(s) could not be attributed to a deficit in tone perception in general.

A second pretest was developed, similar to the first one, to assess the ability of the agrammatic speakers to perceive tonal and minimal phonemic differences. The test had a total of 30 minimal pairs consisting of 10 minimal pairs distinguished by lexical tone; 10 minimal pairs distinguished by phonemes; and 10 minimal pairs with neither phonemic nor tonal differences (sameness condition). The participants were asked to judge whether the pair of words they heard were different or the same, by pointing to a red card and green card, respectively. There was a break halfway through the task. Only five agrammatic speakers performed this task. Examples of lexical tone minimal pairs and phonemic minimal pairs are given in (3a) and (3b), respectively.

Lexical tone minimal pair			Phonemic minimal pairs		
(3a)	*pómà*	'walking stick'	(3b)	*pám'*	to sew'
	pòmá	'to hit		*'tám*	'to take'

The number of correctly answered trials was counted separately for each of the two tonal tests.

Test for assessing reference of time (TART)

The African version of the Test for Assessing Reference of Time (TART: Abuom & Bastiaanse, 2010) was adapted to Akan for this study. The African TART has both a comprehension and a production subtest. All participants of the current study completed both tasks with the exception of three speakers with agrammatic aphasia (P3, P9, and P10) who withdrew from the production task.

Comprehension TART

For the comprehension subtest, a spoken-sentence to picture matching paradigm was developed. A total of 18 transitive verbs (e.g.,"to pour") was used, out of which 16 and 2 verbs were used to create the experimental and practice items, respectively. Each of the 16 experimental verbs appeared three times; once in each time frame, and thus making a total of 48 experimental items. The test began with 6 practice items that consisted of 2 verbs, with each verb inflected for the present habitual, the past and the future to capture all three time frames. The order of the 48 items was randomized. Each action was depicted by two pictures with one placed above the other (see Figure 1). Target pictures for the future and the pastime frames were always contrasted by a picture with the same action in the present time reference, because pictures of past and future are not always easy to distinguish. The items targeting for habitual present were always contrasted with a picture referring to the completed action. An example of a comprehension item is given in Figure 1.

(3) Experimenter: *Pàpá* *nó* *dìì* *ànkáá* *nó*.
Man$_{NOM}$ the ate orange$_{ACC}$ the
The man ate the orange.

A pair of pictures was presented to the participants and a sentence with the target verb depicting a particular time frame was read aloud by the experimenter. The participants had to point to the picture that matched the spoken sentence. The participants were corrected and given feedback during the practice items but no further feedback was given during the main test. The two tests were performed on different days and each test

Figure 1. Example of the Akan TART-comprehension, with the target sentence "the man ate the orange", as in (3).

session lasted for about an hour, with breaks in between. For the scoring, a response was correct when the participants pointed to the picture that matched the time frame encoded in the sentence read out loud by the experimenter.

Production TART

For production, a sentence completion task was used, in which participants were prompted to produce the target verb forms. Similar to the Comprehension TART, a total of 18 transitive verbs, with each verb representing actions in three different time frames, present, past, and future, were tested. The test began with six practice items that consisted of two verbs, with each verb inflected for the present habitual, the past and the future to capture all three time frames. Overall, 16 experimental verbs were used, and each (experimental) verb appeared three times; once in each time frame. This made a total of 48 experimental items. All verbs were presented in sentences that began with a lexical adverb corresponding to the time frame of the verbs. A complete list of the verbs is provided in Appendix A3. Coloured

photographs were used to depict completed, ongoing, and future actions. These actions corresponded to past tense, present habitual, and future tense, respectively. Each item consisted of two pictures, placed side by side, and each picture depicted a different action. Each picture was presented with a root verb written (in bold) above it (see Figure 1). This was to avoid verb retrieval difficulties.

(4) Examiner: *Dá bìáá, pàpá nó hwìé mìlìkè nó. Dá bìáá, pàpá nó .*
Day every, man the pour$_{HAB}$ milk the. Day every man the.
'Every day, the man pours the milk. Every day the man. '

Participant: *nóm mìlìkè nó.*
drink$_{HAB}$ milk$_{ACC}$ the
'drinks milk'

The experimenter first mentioned the verb (above each picture) to the participants in order to prevent them from producing a non-target verb which may also refer to the same action. The experimenter then read out loud a sentence (see Figure 2) that described the action in the left picture. The experimenter continued to read the second sentence until he reached the point where the participants were to produce the target verb and the object to complete the sentence. The order of the items was randomized, and no two items in the same time frame were presented consecutively. No feedback was given to the participants except during the trial sessions.

All responses were recorded on a Mobile-Audio digital recorder, and transcribed for scoring by three native speakers. A response was judged correctly when the tones were correctly assigned to the verb indicating the correct time frame. A response was incorrect when the time frame of the response was not recognizable. The inter-raters reliability of all three raters showed an item by item agreement of 95% for habitual, 100% for future, and 91% for past verbs produced.

The results on the production test were analyzed both quantitatively and qualitatively. The quantitative analysis consisted of the computation of correct and incorrect responses produced by the participants. For the qualitative analysis, errors were categorized post hoc into four main types, namely substitution, omission, shortened tone and other errors. The substitution errors had six subcategories: (1, 2) past substituted by the habitual, and vice versa (3) past substituted by the present progressive, (4) habitual substituted by the present progressive, (5) future substituted by the habitual, and (6) past substituted by the

Figure 2. Example of the Akan TART-production pictures depicting present habitual aspect in Akan. The Akan verbs *twerɛ*: to write and *kan*: to read, as in (4) are written above the respective pictures.

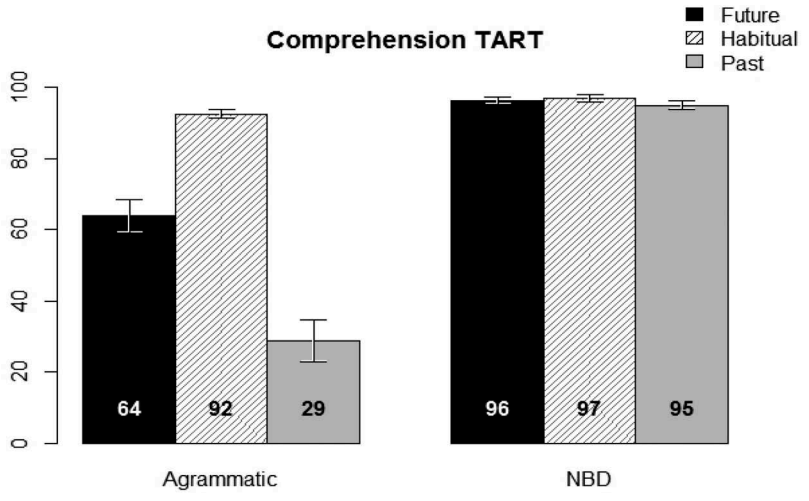

Figure 3. Percent mean accuracy scores per condition per group of participants in comprehension-TART, including error bars.

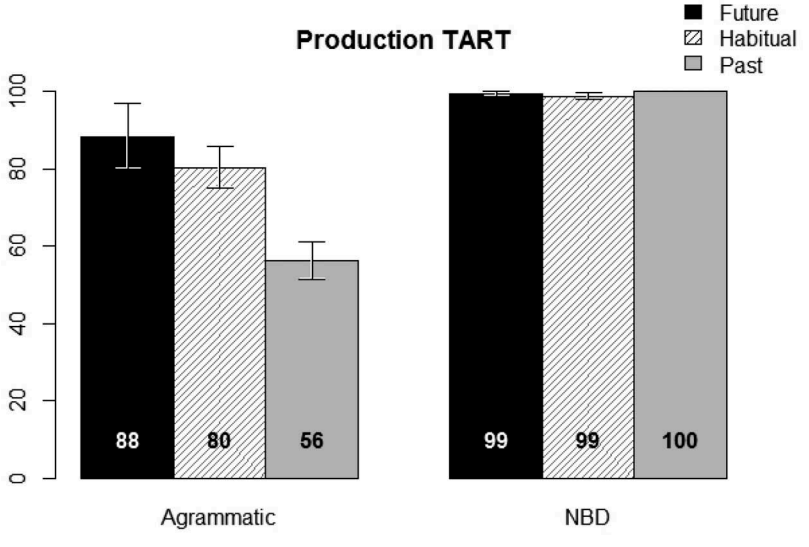

Figure 4. Percent mean accuracy scores per condition per group of participants in comprehension-TART, including error bars.

future. The category "shortened tone" applied only to a verb in the past form whose last syllable had to be prolonged with its corresponding tone. Other errors were lexical errors (eg. *hwane* "to peel" instead of *bobɔ* "to fold").

Statistical analysis

To test for differences between the NBDs and the agrammatic group, across conditions, *a generalized linear mixed-effects modelling* (GLMM) was performed using the *glmer* 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). Generalized linear mixed-effects regression modelling was used in this analysis because of its robustness in accounting for series of random effects of items and participants. Accounting for the variation across participants and items was critical for the current study due to the relatively small item and group sizes. The dependent variable (Score) of the model was accuracy (1 = correct, 0 = incorrect) with random effects factors for items and participants. The initial complete model included the fixed effects Group (Agrammatic and NBDs), Condition (habitual, future, and past), and Task (comprehension and production), and the interactions between these variables. To account for variability across participants and conditions, the model also included random slopes for Condition per Participant. Since the model output showed a ceiling performance of NBD group, only the data of the agrammatic group were considered for further analysis. In this case, the fixed effect "Group" was excluded from the model. The best model (see Table 2 for the complete model), which included an interaction between Task and Condition, was chosen based on the AIC and the log likelihood ratio tests of the full model with the effect (interaction) in question against the model without the effect (interaction) in question (with significance defined as $p < .05$).

Results

Tone discrimination

Table 1 shows the performance of five agrammatic speakers on the non-linguistic and the linguistic (lexical) discrimination tasks. With the exception of patient P4 (who scored 72%), all the five patients performed at least 90% correct on the non-linguistic version, and above 87% correct on the linguistic version.

Test for assessing time reference (TART) in Akan

The performance of the agrammatic speakers and the non-brain-damaged speakers of Akan, on both comprehension and production of time reference in Akan is captured in Figure 3 and 4, respectively. The individual scores for both comprehension and production are reported in Appendix B1. The model including the fixed effect Group (Agrammatic and NBD) showed that the accuracy score of the NBDs was significantly higher than the accuracy score of the agrammatic speakers in both comprehension ($\beta = 2.86$, SE = 0.38, $z = 7.53$) and production ($\beta = 4.33$, SE = 0.67, $z = 6.50$), and there was no pattern observed across conditions (present habitual, past, and future) for the

Table 1. Percentage of accuracy scores on non-/linguistic tone discrimination task.

Patients	Non-linguistic tone Discrimination (%)	Linguistic (lexical) tone discrimination (%)
P1	98	93
P2	90	97
P3	92	87
P4	72	87
P10	90	93
Mean	**88.4**	**91.4**

Table 2. Generalized linear mixed model output on the Akan agrammatic speakers' accuracy.

GLMER output				
Term	β	Standard error	*z*-Value	*p*-Value
(Intercept: Condition = Fut, Task = Comp)	0.6292	0.2852	2.206	$p = 0.0274$*
Condition = PresHab	1.9766	0.4336	4.559	$p < 0.001$***
Condition = Past	−1.5779	0.3594	−4.391	$p < 0.001$***
Task = Prod	1.5942	0.3700	4.309	$p < 0.001$***
ConditionPresHab:TaskProd	−2.6619	0.5376	−4.951	$p < 0.001$***
ConditionPast:TaskProd	−0.4461	0.4570	−0.976	$p = 0.3290$
Post-Hoc Analysis: Multiple Comparisons of Means (Tukey Contrasts)				
PresHab.Comp – Fut.Comp	1.9766	0.4336	4.559	$p < 0.001$***
Past.Comp – Fut.Comp	−1.5779	0.3594	−4.391	$p < 0.001$***
Past.Comp – PresHab.Comp	−3.5545	0.4412	−8.056	$p < 0.001$***
PresHab.Prod – Fut.Prod	−0.6853	0.4884	−1.403	$p = 0.7115$
Past.Prod – Fut.Prod	−2.0240	0.4661	−4.343	$p < 0.001$***
Past.Prod – PresHab.Prod	−1.3387	0.4315	−3.102	$p = 0.0223$

Note: Fut = Future; Comp = Comprehension; PresHab = Present Habitual; Prod = Production.
The glmer output was from the model that included an interaction between Task and Condition as well as random slopes for Condition per Participant and random effect for Items: Mod<-glmer(Correct~Condition*Task +(1+ Condition|Participant) + (1|Item), data)

NBDs. The data of the NBDs were not included for further analysis, and thus, the fixed effect "Group" was dropped.

There was a significant interaction between Condition and Task (output of model with no interaction versus a model with a two-way interaction: X^2 (2) = 29.46, $p < 0.001$, with a lower AIC value for the model with interaction). That is, there was a significant dissociation between the future and the habitual time references in the comprehension TART (β = −1.98, SE = 0.43, z = −4.56, p < 0.001) but not in the production TART (β = 0.69, SE = 0.49, z = 1.40, p = 0.712).

Comprehension TART

For comprehension, the agrammatic speakers scored significantly lower on pastime reference than the future (β = −1.58, SE = 0.36, z = −4.39, $p < 0.001$) and the habitual time references (β = −3.55, SE = 0.44, z = −8.06, $p < 0.001$). There was a significant difference between the future and the habitual time frames as well (β = 1.98, SE = 0.43, z = 4.56, $p < 0.001$), with the former being more difficult than the latter.

Production TART

In production, there was no significant difference between the future and the habitual time frames (β = −0.69, SE = 0.49, z = −1.40, $p = 0.712$). This explains the significant interaction effect in the model with interactions between Condition and Task.

Similar to the comprehension data, the agrammatic speakers were less accurate in producing Akan pastime reference than the future (β = −2.02, SE = 0.47, z = −4.34, $p < 0.001$) and the habitual (β = −1.34, SE = 0.43, z = −3.10, $p = 0.02$) time references.

Error types in production

The distribution of all errors produced by the agrammatic group is reported in Table 3. Overall, the substitution errors were the most prevalent (47 out of a total of 82 errors). The past verbs were substituted most frequently by either the present habitual (Hab), present

Table 3. Distribution of error types.

	Substitution								
Patient	Ps-Hab	Ps-PP	FU-Hab	Hab-PP	Hab-Ps	Ps-FU	Short tone duration	Omission	Others
P1	5	1		2	1				1
P2	2		4	2			5	2	7
P4	2			2		4	1		1
P6	0	0		2			8		0
P7	1	4		1			3		1
P8	2	1		6			1		3
P9	0	4		1			1		1
Total	**12**	**10**	**4**	**16**	**1**	**4**	**19**	**2**	**14**
Direction of time reference substitution errors (%)									
	Present		*Past*		*Future*				
	89%		**2%**		**9%**				

Note: Ps-Hab = Past to Habitual substitution; Ps-PP = Past to Present Progressive substitution; FU-Hab = Future to Habitual substitution; Hab-PP = Habitual to Present Progressive substitution; Hab-Ps = Habitual to Past substitution; Ps-FU = Past to Future substitution.

progressive (PP) or the future (FU). Other errors were the use of non-target verbs which could also describe the same actions depicted in the pictures.

Direction of the time reference substitution errors showed that whenever a target time frame was substituted, the agrammatic speakers preferred using a present time frame (89%), followed by the future (9%). The past was least preferred (2%). The agrammatic speakers predominantly substituted the pastime reference by a present time reference (either the present habitual or the present progressive). This error type accounts for 27% of the total number of errors. Some of the errors made on the past were shortened duration of tone on the last syllable of the verbs, and this made up 23% of the overall errors produced. Nonetheless, a further look at the individual errors indicates that not all agrammatic speakers had problems with the pastime tone prolongation: Only P2, P6, and P7 made many of these errors (5, 8, and 3, respectively).

In sum, in both production and comprehension, verb forms referring to the past are more affected in Akan speakers with agrammatic aphasia than verb forms referring to either present habitual or future. Nevertheless, in comprehension, there was a dissociation between the present habitual and the future, with the latter being more affected, although both are relatively preserved in production. The error analysis also indicated that whenever there were time frame substitution errors, these errors were towards the direction of the present habitual. The non-linguistic tone task demonstrated that tone per se is relatively preserved in Akan speakers with agrammatic aphasia.

Discussion

The current study examined whether the observed differences in past versus non-past (present and future) time reference in languages that use morphological inflection also hold for languages that express time reference through grammatical tone. Further, the current study examined whether an impairment (if any) in grammatical tone could be attributed to tone perception in general or to the temporal reference function of Akan verbs. The results demonstrated that reference to past is selectively impaired regardless of the form in which it is expressed. Nevertheless, in comprehension, the agrammatic speakers performed poorer on the future than on the present habitual time frames. The

data also showed that the time reference deficit in Akan agrammatic speakers cannot be reduced to their inability to distinguish between (non-linguistic or linguistic) tones, although only five agrammatic patients participated in the non-linguistic tone task. These findings are further discussed in this section.

Difficulties in pastime reference regardless of form

The current data provide evidence that in agrammatism, reference to the past is more impaired than reference to the non-past, not only in languages that use morphological inflection but also in languages that use tone to mark temporal reference. This is consistent with the findings of previous studies in Indo-European languages that express time reference through grammatical morphology (Abuom & Bastiaanse, 2012; Bastiaanse, 2008, 2013; Bastiaanse et al., 2011; Bos & Bastiaanse, 2014; Dragoy & Bastiaanse, 2013; Martínez-Ferreiro & Bastiaanse, 2013), even though some studies did not show such an asymmetry (Burchert et al., 2005; Wenzlaff & Clahsen, 2004; Faroqi-Shah & Friedman, 2015; Fyndanis et al., 2018a). This result also provides further evidence for the PADILIH (Bastiaanse et al., 2011). The PADILIH argues that verb forms that make reference to the past require discourse linking. This makes pastime reference more complex than present or future time references which are not discourse linked (Zagona, 2013). According to Avrutin (2000, 2006), discourse linking is compromised in Broca's aphasia, and as a result, reference to the past is expected to be affected in agrammatism. Based on the PADILIH, our prediction was that if the problems with pastime reference are due to deficit to express this notion by grammatical inflection, the pastime reference in Akan should have been spared because tone rather than affix is used. However, past time reference is selectively impaired in agrammatic speakers of Akan; hence, it is not grammatical inflection that is the core of the problem but expressing time reference to the past by a verb form.

However, the comprehension data showed a deficit in the future time frame as well, and this is not consistent with the predictions of the PADILIH. According to Bastiaanse (2011), who follows Zagona (2003, 2013), the future does not require discourse linking since there is no event yet to link the speaking time to. The PADILIH claims that the future time reference is a subclass of present (Zagona, 2013), and hence, future is not discourse linked. The PADILIH further categorizes the present and the future as non-past, and thus, reference to either of them should be relatively spared. This was not the case in the current comprehension data. Nonetheless, this observed asymmetry between the future and the present (habitual) has also been found in other studies (Bastiaanse et al., 2011; Martínez-Ferreiro & Bastiaanse, 2013; Nanousi et al., 2006). Nanousi et al. (2006) reported that in production, Greek-speaking agrammatic individuals showed a significantly poorer performance in simple future than simple present. Additionally, Martínez-Ferreiro and Bastiaanse (2013) found that in comprehension, Spanish and Catalan individuals with non-fluent aphasia showed a dissociation between the present and the future, with the former being better preserved, although such difference did not occur in production. Similarly, Bastiaanse et al. (2011) also reported that in comprehension, English, Chinese, and Turkish agrammatic individuals showed a dissociation between present reference and future reference, with the latter being more difficult. Furthermore, Zagona's (2003) anaphoric view on the present and the future time references suggests a difference between these two time frames even though both are not discourse linked. This difference lies in how both present and future relate with the speech time and

event. While the former shows a simultaneous relationship between speech time and event, the latter does not, since there is no event yet. Further exploration to understand the extent to which comprehension of the future and the present may differ is needed.

On the question of whether grammatical affixes make time reference difficult to process, the observed dissociation between the present and the future could not be attributed to extra processing load which may have been added by presence of the grammatical affix (prefix *"bɛ/ be"*) in the future time reference. The following are the reasons why we rule out such an interpretation. First, if the extra morpheme posed additional processing demands, the past should have been better preserved than the future, since the past is only marked by tone, and thus, does not have an extra linguistic unit such as an affix. Second, since this dissociation was not replicated in the production data, it is probably not due to the future requiring discourse linking, as argued by Avrutin (2000). Thirdly, the error analysis shows that the addition of grammatical affixes does not make a particular time frame difficult to process. The error pattern indicated that some of the participants with agrammatic aphasia preferred the present progressive aspect to the habitual aspect although the Akan verbs in their present progressive form require the use of the prefix '*re-*' in addition to tone. This suggests that grammatical morphology *per se* is not a restraint for verb production, at least for some of the participants of this study.

Tonal height, duration, and the past

Time reference in Akan is expressed through grammatical tone, and thus, it is important to tease apart the effect of time reference and tone. The Akan past is distinguished from the present habitual by (1) tonal height and (2) tonal duration. First, for tonal height, all Akan monosyllabic verbs have a high tone (HT) and a low tone (LT) with a longer duration, on the present habitual and the past, respectively. For disyllabic verbs, the present habitual has an LT (on the first syllable) and HT (on the second syllable), while the past has LT on both syllables. Thus, if tonal height (pitch) perception per se was disrupted in Akan agrammatic speakers; then, there would be an equal distribution of errors on both the past and the present habitual time references. However, the results indicated that this is not the case – more errors were made in the past than the present habitual. Additionally, the non-linguistic tone as well as the linguistic (lexical and phonemic) tone discrimination tasks which aimed at assessing the general perception of tonal differences showed a relatively intact processing. Although only five agrammatic speakers participated in the non-linguistic tone task, the pattern of errors observed in the TART (which involves grammatical tone) in the other five agrammatic speakers was not different. If tone in general was disrupted, an equal distribution of errors across all time frames should have been observed, since the non-past time references also involve the use of tone. This was not the case. Therefore, the Akan agrammatic speakers' deficit in pastime reference cannot be reduced to their inability to perceive tone in general.

Secondly, for tonal duration, the analysis of the error types revealed that some of the errors made on the past verbs were the result of the failure to prolong the tone. This is inconsistent with previous studies that have shown that tonal duration is relatively intact in Thai nonfluent aphasia (Gandour & Dardarananda, 1984; Gandour et al., 1992a, 1992b). Thai has five tones, with the mid tone and the falling tone having the longest and the shortest tone durations, respectively. Gandour and colleagues found that Thai speakers with nonfluent aphasia have a preserved ability to control relative differences in tone duration associated with the Thai phonological contrast in vowel length (Gandour &

Dardarananda, 1984; Gandour et al., 1992a, 1992b). Note, however, that Gandour and colleagues examined lexical tone and not grammatical tone.

In the current data, only three patients (P2, P6, and P7, see Table 1) made a substantial number of errors on the tonal prolongation, therefore, one has to be cautious in concluding that tone prolongation is impaired in Akan agrammatic speakers. Apart from this, the variation among the agrammatic speakers may be due to severity of aphasia (Gandour et al., 1988, 1992a). Since aphasia severity was not measured in this study, a well-defined acoustic and phonetic investigation of the extent to which tone duration is affected is recommended for future research.

In conclusion, reference to the past is more affected than reference to the non-past in Akan agrammatic speakers, as predicted by the PADILIH. The PADILIH claims that pastime reference is difficult because it requires discourse linking, which has been found to be problematic in agrammatism. Therefore, the form in which time reference is expressed, whether through grammatical affixes or tone, does not matter as much as the notion of time. Although some participants with agrammatic aphasia were unable to prolong the tone in the past verb forms correctly for each single item, the current data do not provide evidence to conclude that tone duration was the underlying cause of errors on the past. Taken together, there is a basic effect of time reference, particularly to the past, which may be overlaid by the effect of tonal duration, but which cannot be explained by tonal duration.

Notes

1. We realize that the term "inflectional morphology" may be confusing, because changes in tone to denote tense are, by some linguists, considered to be inflectional as well (see, e.g., Palancar and Léonard, 2016, who distinguish lexical tone and inflectional tone). Here, we mean by "inflectional morphology" and "inflectional morphemes" only those bound morphemes that are added to the verb stem, such as English *-s, -ed,* and *-ing*. The aspectual adverbs as used in Chinese and Standard Indonesian are referred to as "free grammatical morphemes".
2. The Akan low and high tones are represented as [ˋ as in à] and [ˊ as in á], respectively. However, these pitch differences are not strictly level in real speech (Abakah, 2000, 2005; Laver, 1994), and therefore we refer to them as relative.
3. Patients were tested at different times, and the first five patients were tested at a time the Tonal Screening Test was not available yet.

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Appendices

Appendix A1. Demographic data of the agrammatic speakers and the none-brain-damaged speakers.

Participants	Age	Gender	Handedness	Education (years)	Months PO	Etiology/Lesion site	Hemiplegia	BDAE Scores (%)
Agrammatic speakers								
P1	69	M	Right	13	24	CVA Left temporo-parietal	none	91
P2	37	M	Right	16	7	Left fronto-parietal infarct	right	96
P3	19	F	Right	12	7	iCVA Acute left-fronto-parietal-occipital infarct	Right	100
P4	49	M	Right	10	25	CVA Left middle cerebral artery	none	100
P5	76	F	Right	16	12	hCVA left	Right	98
P6	56	M	Right	12	24	CVA left	Right	100
P7	61	M	Right	16	36	hCVA left	Right	94
P8	55	M	Right	12	15	hCVA left	Right	100
P9	50	M	Right	16	28	iCVA left	Right	-
P10	67	F	Right	10	7	hCVA left	Right	96
Non-brain-damaged participants								
NBD1	45	F	Right	9				
NBD2	35	F	Right	9				
NBD3	52	F	Right	16				
NBD4	44	M	Right	16				
NBD5	71	F	Right	16				
NBD6	37	M	Right	12				
NBD7	63	M	Right	16				
NBD8	48	M	Right	16				
NBD9	58	M	Right	12				
NBD10	58	F	Right	9				

Appendix A2 Spontaneous speech sample analysis

Patients	Speech rate(wpm)	MLU	Ungrammatical sentences	BDAE Scores (_/46)
P1	95	4.8	14 (19.5%)	42
P2	34	2.5	16 (23.5%)	44
P3[a]	-	-	-	-
P4	86	3.8	25 (38.4%)	46
P5	63	3.77	11 (17%)	45
P6	66	4.2	14 (23%)	46
P7	48	3.79	14 (24%)	44
P8	79	4.35	13 (20%)	46
P9	58	3.96	16 (25%)	44
P10	66	3.55	12 (18.6%)	42
NBDs' mean	136	10.5	1.35 (3.2%)	46
NBDs' range	101 – 156	8.45–12.8	0 – 8%	

Note: MLU = Mean Length of Utterance; wpm = word per minute; BDAE = Boston Diagnostic Aphasia Examination. BDAE: subtest of auditory comprehension of nouns, verbs, letters and numbers (both colours and forms were untranslatable to single words in Akan)

P3 did not produce the required speech sample size for a reliable analysis. However, there was a consensus between the Speech and Language Therapist and the neurolinguist that P3 was agrammatic aphasic patient.

Appendix A3. Verb pairs used in the Akan-TART

Verbs in Akan	Translation	Verbs in Akan	Translation
Examples			
susu	to measure	twitwa	to cut
Test items			
kan	to read	twer	to write
di	to eat	hwane	to peel
pia	to push	twe	to pull
pepa	to mop	pra	to sweep
pam	to sew	wene	to knit
sensen	to sharpen	bu	to break
nom	to drink	hwie	to pour
to	to iron	bob	to fold

Appendix B1. Percentage of individual scores consisting of 16 items per each time frame

Participants	Past (%)	Habitual (%)	Future (%)
Comprehension-TART			
P1	19	94	38
P2	56	88	56
P3	19	100	63
P4	13	94	50
P5	25	94	75
P6	44	88	88
P7	62	94	69
P8	6	88	81
P9	19	94	63
P10	25	94	56
Mean	29	92	64
Production-TART			
P1	56	81	94
P2	38	81	38
P3	-	-	-
P4	56	81	100
P5	-	-	-
P6	50	88	100
P7	50	88	100
P8	75	50	94
P9	69	94	94
P10	-	-	-
Mean	56	80	88