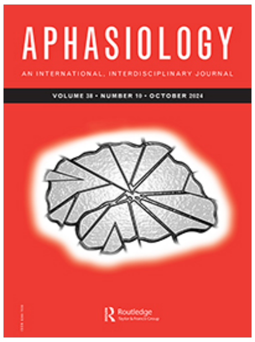

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Time reference in French-speaking people with fluent and non-fluent aphasia (part I): tense dissociations, task effects and cognitive predictors

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ABSTRACT

Background: People with fluent and non-fluent aphasia frequently have time reference deficits, which could be more pronounced for the past than for the present and future tenses. However, this performance pattern (past < non-past) is not consensual and might depend on the type of task used. Furthermore, the influence of cognitive processes on time reference deficits remains little explored, as does the origin of these difficulties (e.g. pre-phonological, morpho-phonological).

Aims: The primary aims of the study were (1) to identify time reference deficits and (2) dissociations between tenses in French speakers with fluent and non-fluent aphasia and (3) to specify the effect of tasks on performance and tense dissociations. Secondly, our study also aimed to determine whether time reference deficits were (4) influenced by cognitive functions and (5) explained by pre-phonological or morpho-phonological deficits.

Methods & procedures: Twenty-one French-speaking participants with fluent and non-fluent aphasia and 21 matched control subjects performed three tasks assessing time reference (verb inflection production, verb inflection selection, and adverb selection) and five neuropsychological tests (verbal and non-verbal working memory, inhibition, flexibility, and temporality). Quantitative and qualitative analyses were conducted.

Outcomes & results: Participants with fluent and non-fluent aphasia had worse performances than controls on the three time-reference tasks. The performance of the participants with fluent and non-fluent aphasia was quantitatively similar but qualitatively different on the verb inflection production task (i.e. different error types). A main task effect was also found: the verb inflection production task was the only one to show worse performances in the past than in the present and future. Regarding cognitive predictors, verbal working memory and temporality were linked to the three tasks assessing time reference. In contrast, non-verbal working memory was associated only with the two selection tasks, possibly related to the mental

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timeline. Finally, task analysis suggested a pre-phonological (encoding of diacritic features deficit) rather than a morpho-phonological origin.
Conclusions: Our study is the first to replicate time reference deficit in French speakers with aphasia. It suggests that the type of task might influence the performance profiles observed and help to shed light on the origin of the difficulties. Cognitive functions that have rarely been investigated before may also influence performance. These results have important clinical implications by questioning the tasks used to assess time reference. They also underline the importance of identifying the origin of difficulties in proposing targeted treatment.

Introduction

People with aphasia (PWA) may present with a variety of language disorders, including morphosyntactic deficits. Among the morphosyntactic components, tense production seems particularly problematic, with deficits in time reference frequently reported in people with non-fluent aphasia and to a lesser extent in people with fluent aphasia (e.g., Bos & Bastiaanse, 2014; Jonkers & de Bruin, 2009). However, not all tenses may be similarly affected in aphasia. Indeed, numerous studies have shown that people with fluent and non-fluent aphasia have greater difficulties with past tenses than with other tenses (e.g., Bastiaanse, 2013; Bos & Bastiaanse, 2014; Dragoy & Bastiaanse, 2013; Martínez-Ferreiro & Bastiaanse, 2013). This error pattern was also found in a recent meta-analysis that analyzed the performance of 232 individuals with fluent and non-fluent aphasia from 23 studies on time reference (Cordonier et al., 2024). This meta-analysis showed worse performances on past tense than on present and future tenses. Interestingly, these results were observed for both participants with fluent and non-fluent aphasia.

Taken together, these findings support the PAst DIscourse LInking Hypothesis (PADILIH; Bastiaanse, 2013; Bastiaanse et al., 2011), which postulates a specific past tense deficit due to "discourse linking". Indeed, as the speech time does not coincide with the time of the described event, discourse linking must be established. This discourse link is costly in processing resources, leading to difficulties with past tenses in PWA (Avrutin, 2000, 2006). Conversely, such a link is not necessary for the present and future tenses (considered a subclass of the present). These tenses would, therefore, be easier for PWA.

According to Bastiaanse (2013), the PADILIH might be language independent. This assertion is supported by cross-linguistic studies that have shown a specific past tense deficit in multiple languages, such as English, Turkish and Dutch (e.g., Bastiaanse, 2013), Russian (e.g., Dragoy & Bastiaanse, 2013; Yarbay Duman & Bastiaanse, 2009), Serbian (e.g., Kljajevic & Bastiaanse, 2010), Catalan and Spanish (e.g., Martínez-Ferreiro & Bastiaanse, 2013). However, some languages remain unexplored, and, for instance, no study has demonstrated a time reference deficit in French speakers with fluent and non-fluent aphasia, nor a specific past tense deficit in French. The exploration of these uncharted linguistic territories could lead to new insights in PADILIH research.

In addition to these linguistic gaps, the PADILIH also faces conflicting results in the literature, with some studies showing no dissociation between past and non-past tenses (e.g., Clahsen & Ali, 2009; Fyndanis et al., 2012; Varlokosta et al., 2006). One hypothesis to explain these discrepancies relies on methodological issues, particularly the type of tasks used and the cognitive demands they place on participants (Nerantzini et al., 2020).

Effect of tasks and cognitive predictors on performance

Worse performance in past tenses has mainly been demonstrated with a specific priming task, the Test for Assessing Reference of Time (TART; Bastiaanse et al., 2008). This task involves transposing the tense of a source sentence associated with a photograph to a target sentence associated with a second photograph (e.g., *in this picture, the man just ate an apple* ➔ *peel – in this second picture, the man just . . . an apple* (expected answer: *peeled*)). However, other experimental paradigms have been used in studies of time reference in aphasia. These paradigms include transformation tasks (e.g., *Yesterday the man watered the flowers* ➔ *Tomorrow, the man . . . the flowers* (expected answer: *will water*)), sentence completion or production tasks according to a temporal adverb, with or without forced-choice answers (e.g., *eat – tomorrow, the man . . . the apple* (expected answer: *will eat*)) and grammaticality judgment tasks. Some studies using these other experimental paradigms (Burchert et al., 2005; Clahsen & Ali, 2009; Fyndanis, Arcara, Capasso, et al., 2018; Kok et al., 2007) have found no dissociation between past and present/future tenses in people with fluent and non-fluent aphasia, raising the question of task effect.

The tasks assessing time reference seem to differ in terms of complexity. Indeed, two meta-analyses (Cordonier et al., 2024; Faroqi-Shah & Friedman, 2015) have demonstrated a task effect on tense production: overall performance of PWA, regardless of tense, was lower in the priming tasks and the tasks of completion/production of sentences according to a temporal adverb. Conversely, forced-choice completion tasks were more successful. Three studies also directly compared PWA performance on different tasks. Kok et al. (2007) found that their nine participants with agrammatism had more difficulty with tense in a task consisting of inflecting verbs while putting the words in the sentence back in order than in an inflection task alone. Nerantzini et al. (2020) also reported worse performance in a priming task compared to narrative tasks (i.e., elicited picture description and semi-standardized interview) in seven agrammatic participants, with a past tense deficit observed only in the priming task. Recently, Diouny and El Ouardi (2023) found poorer tense performance in a priming task than in a transformation task in five participants with agrammatism. All these authors related these findings to the processing load of time reference and the processing resources of PWA. Although these results are based on a limited number of studies with small sample sizes and only participants with non-fluent aphasia, they have several implications.

Firstly, they suggest an important role for processing resources in time reference. To our knowledge, only a few studies have analyzed the impact of cognitive variables on tense in PWA. These studies (Fyndanis, Arcara, Capasso, et al., 2018; Fyndanis, Arcara, Christidou, et al., 2018) tend to show a link between verbal working memory capacity and time reference in people with fluent and non-fluent aphasia. Although this relationship has been statistically proven only in transformation tasks, it is likely that verbal working memory is also involved in other types of tasks assessing time reference (e.g., sentence completion with forced-choice answers), albeit to a lesser extent (Auclair-Ouellet et al., 2019; Nerantzini et al., 2020). Moreover, this link could be specific to the verbal modality of working memory. Indeed, a recent study (Fyndanis et al., 2022) demonstrated a significant main effect of verbal working memory, but not of non-verbal working memory, on the performance of healthy subjects in transformation tasks assessing several morphosyntactic phenomena. They concluded that morphosyntactic production – including tense production – relies on domain-specific (i.e., verbal) memory resources.

On the other hand, other cognitive functions, such as inhibition or flexibility, have never been studied in relation to time reference. These cognitive functions could influence performance, as most tasks involve inhibiting time frames given in source sentences or previous stimuli, or disregarding incorrect forced-choice answers, as well as flexibility to switch from one tense to another depending on the time frame of the stimulus. The conceptual-semantic abilities of temporality, such as understanding temporal adverbs (e.g., understanding that “in several years” refers to the future), could also influence performance insofar as time reference tasks generally use temporal adverbs to induce past, present, or future (Patterson & Holland, 2014). To date, this understanding of adverbs has been tested only briefly, using, for example, calendars (e.g., Faroqi-Shah & Thompson, 2007). Consequently, no clear conclusions can be drawn on the conceptual-semantic skills of temporality of PWA and their influence on time reference. Therefore, further research is necessary to deepen our understanding of how various cognitive functions contribute to the production of tenses in PWA and their potentially different impact on different tasks.

A second implication relates to the effect of task complexity on tense dissociations. In their meta-analysis, Faroqi-Shah and Friedman (2015) conducted four separate ANOVAs on the performance in four task types (priming (TART), completion with or without forced-choice and grammaticality judgment tasks; see below for a more detailed description) and demonstrated a tense effect (i.e., past < non-past) only for the TART task. No tense effect was observed in the other tasks (e.g., grammaticality judgment or forced-choice sentence completion). The authors concluded that the tense effect (i.e., past < non-past) could be mediated by the TART task, which would involve specific demands, particularly because the action is not represented on the photographs in the past tense condition. However, the literature shows that the results are not so consistent.

Recently, Cordonier et al. (2024) thus used other statistical analyses in their meta-analysis and found no interaction between tense and task. Furthermore, the task effect on tense dissociations (past vs future) was also tested in a recent study with English, Greek, Italian, and Russian PWA (Fyndanis et al., 2023). The authors administered the TART and a transformation task. Numerous intra-individual dissociations between tasks and tenses were observed in the PWA. Interestingly, tense direction (i.e., past < future or future < past) was not related to the type of task: poorer performance in the past was observed both in the transformation and in the TART tasks. The authors concluded that the poorer performances in the past cannot be explained solely by the use of the TART. Consequently, further studies are needed to clarify these inconsistent findings regarding task-based tense dissociations.

While including several tasks is relevant for analyzing the effect of task complexity on time reference performance and tense dissociations, it also has a second advantage i.e., to clarify the origin of time reference deficits in relation to theoretical models.

Origins of tense deficits

Producing the correct inflected verb form first requires a pre-phonological process, referred to as the "DER process" – "encoding and retrieval of diacritic features" – by Faroqi-Shah and Thompson (2007). It consists of *encoding* the diacritic features corresponding to the temporal frame (i.e., past, present, future), then *retrieving* the phonological form corresponding to the selected diacritic features. This phonological form could correspond to an inflectional affix (e.g., the *-ed* ending of the past tense) or to a whole word inflected representation of the verb (e.g., *went* for the past tense of the verb *go*) (Faroqi-Shah & Thompson, 2007). When only the inflectional affix is retrieved (typically in the case of regular verbs), a morpho-phonological process follows, which consists of applying an *affixation* rule (e.g., adding the suffix *-ed* to the root of the verb *peel*) (Pinker, 1998; Ullman et al., 1997, 2005) This affixation process would not be necessary for irregular verbs since the whole word inflected representation of the verb is retrieved.

Faroqi-Shah and Thompson (2007) thus conducted several experiments to clarify the origin of verb inflection deficits (pre-phonological versus morpho-phonological). They used forced-choice sentence completion tasks and manipulated two parameters. The first parameter was the temporal context, which induced past tense (e.g., Yesterday, Rob _____ at the meeting; options: speaks, spoke, speak), present tense (e.g., Everyday, John_____ a question; options: asks, asked, ask), future tense (e.g., Tomorrow, John_____ a question: options: will ask, was asking, is asked) or a non-finite verb (e.g., Last year, Rob learned to _____ Russian; options: speaks, spoke, speak). It was hypothesized that a selective deficit in the inflected verb forms (but not in the non-finite verbs) would indicate a deficit in the DER process (i.e., a pre-phonological origin). Morphological complexity (regular verbs, irregular verbs, and derived words) was also manipulated to test the morpho-phonological process of affixation. A selective deficit in regular verbs and derived words would indicate an affixation deficit.

Their results showed high accuracy for non-finite verbs and low accuracy for finite verbs, with a majority of substitution errors from one tense to another (e.g., choosing the present rather than the past form) and an absence of a morphological complexity effect (i.e., regular verbs = irregular verbs). They concluded that verb tense difficulties in aphasia may have a pre-phonological origin (i.e., impairment in encoding the diacritic features and/or retrieving the phonological form corresponding to the selected diacritic features – DER process) rather than a morpho-phonological (i.e., affixation) origin. To take the analysis one step further and to clarify the origin within the DER process (deficit in encoding diacritic features *or* in retrieving the phonological form), they then drew on the results of a previous study (Faroqi-Shah, 2006). This study confirmed difficulties in completing sentences with an inflected verb (e.g., After Mary moved the sofa, she ___ her back; options: strained, strains, will strain) but showed relatively spared performance in completing sentences with a temporal adverb (e.g., The tourist ate pizza____; options: everyday, yesterday, next week). The authors concluded that the encoding of diacritic features may be preserved insofar as PWA could correctly associate a temporal adverb with a verb inflection. Thus, the time reference deficits rather lie in the retrieval of the phonological forms corresponding to the selected diacritic features.

It is important to note that this DER model – like most inflectional morphology models – has only been tested with people with non-fluent aphasia, given their characteristic agrammatism, raising questions about the origin of tense production difficulties in people with fluent aphasia. Quantitatively, people with fluent aphasia generally perform slightly better (Bos & Bastiaanse, 2014; Cordonier et al., 2024) or similarly to those with non-fluent aphasia (Dragoy & Bastiaanse, 2013; Jonkers & de Bruin, 2009). Their performance patterns (i.e., dissociations between tenses) are also similar (Cordonier et al., 2024). However, some authors have suggested that these comparable surface manifestations might reflect different underlying disorders.

This assertion is based on analyses of the errors. Indeed, some studies (Bos & Bastiaanse, 2014; Kljajevic & Bastiaanse, 2010) have shown that errors differed between the two groups in a priming task (i.e., TART). Participants with fluent aphasia predominantly made "within-target-time-frame" errors (e.g., substitutions of the simple past by the periphrastic past), while participants with non-fluent aphasia predominantly made "outside-target-time-frame" errors (e.g., substitution of the simple past by the simple present) or unmarked forms. Bos and Bastiaanse (2014) concluded that these error patterns might reflect different underlying disorders. Participants with non-fluent aphasia would have grammatical encoding difficulties: faced with complex grammatical operations, such as tense production, they would reduce the load on grammatical encoding by using simpler, non-discourse-linked verbal forms (typically the present tense). In contrast, people with fluent aphasia would have lexical retrieval difficulties, which, in grammatically complex situations, would prevent them from retrieving the precise verb form.

However, these error patterns are not unanimously found in the literature. For example, Fyndanis, Arcara, Capasso, et al. (2018) observed a majority of time frame repetition errors (i.e., repeating the tense of the source sentence in the target sentence) in a transformation task in both their fluent and non-fluent aphasia participants. Similarly, Dragoy and Bastiaanse (2013) showed largely overlapping performance in their two groups of participants with fluent and non-fluent aphasia, with a majority of non-past substitution errors. Interestingly, divergences between groups were observed only in the most complex conditions and were carried out by only a few participants. Methodological considerations (e.g., task type) could explain these discrepancies.

To summarize, the origin of time reference difficulties, particularly for people with fluent aphasia, remains poorly understood. While the use of different tasks and error analysis has shown promise in shedding light on the underlying cause of these difficulties, very few studies have used them, with contradictory results. More studies using these methods jointly are therefore needed to clarify the origin of time reference difficulties in fluent and non-fluent aphasia.

Aims of the study and hypotheses

The objectives of our study were fivefold. Firstly, we sought to investigate whether time reference deficits were observed in French-speaking people with fluent and non-fluent aphasia, and secondly, whether these deficits were marked by dissociations between tenses (i.e., past, present, and future). Since deficits have been reported in many languages, including Romance languages close to French (e.g., Martínez-Ferreiro & Bastiaanse, 2013), we expected to observe time reference deficits in our French-speaking participants with fluent and non-fluent aphasia. Regarding dissociation patterns, according to the PADILIH, we expected poorer performance in the past tense both in the participants with fluent and non-fluent aphasia (Cordonier et al., 2024).

Our third objective was to analyze the effect of tasks by exploring whether different performances were observed in three different tasks, both in terms of overall deficit and dissociations between tenses. Based on Faroqi-Shah and Friedman (2015) and Cordonier et al. (2024) meta-analyses, we hypothesized that a task involving inflected verb production should be more or selectively impaired compared to completion tasks with forced-choice answers in people with fluent and non-fluent aphasia. Dissociations between tenses (i.e., past < non-past) could be observed only in more complex tasks (i.e., inflected verb production) in people with non-fluent aphasia (Faroqi-Shah & Friedman, 2015; Nerantzini et al., 2020). To date, no research has compared dissociation patterns across various tasks in individuals with fluent aphasia, leaving this question open for investigation.

Fourthly, we aimed to explore the influence of cognitive predictors on performance on each task. We expected an effect of verbal working memory – but not non-verbal working memory – on the performance of people with fluent and non-fluent aphasia (Fyndanis et al., 2022; Fyndanis, Arcara, Christidou, et al., 2018). Regarding other cognitive functions (inhibition, flexibility, conceptual-semantic notion of temporality), the lack of literature on the subject prevented us from establishing clear hypotheses. We hypothesized, however, that these cognitive functions could play a role in time reference.

Finally, the analysis of the three tasks, verb regularity and errors, should enable us to shed light on the origin of the difficulties, our fifth objective. In line with the findings of Faroqi-Shah and Thompson (2007) and Faroqi-Shah (2006), we expected task performance to speak in favor of a deficit in the retrieval of the phonological form corresponding to the diacritic features in people with non-fluent aphasia (see the method for a more precise description of the tasks and their link with the origin of the difficulties). For people with fluent aphasia, the question remains more open, although an origin in the retrieval of the phonological form seems more likely (Bos & Bastiaanse, 2014). No hypothesis was made about the regularity effect (and therefore the morpho-phonological origin) in people with fluent and non-fluent aphasia, given the contradictory results reported in the literature (e.g., Balaguer et al., 2004; Ullman et al., 2005; Wenzlaff & Clahsen, 2004; see; Faroqi-Shah, 2007 for a review).

Before presenting the method section, we briefly describe some relevant background information on French verb morphology.

Background on time reference in French

French conjugation is complex, with many monolectic and periphrastic forms. Only the most frequent forms are detailed below. The past reference is mainly produced by means

Table 1. Example of verb forms for each time reference (past, present and future) for the verb *manger* (to eat).

Reference	Past			Present	Future
French tenses	Imparfait	Passé simple	Passé composé	Présent	Futur
Example	*Il mangeait*	*Il mangea*	*Il a mangé*	*Il mange*	*Il mangera*

of two monolectic forms (the simple past – *passé simple* – and the imperfect – *imparfait*) and one periphrastic form (the compound past tense – *passé composé* – made up of an auxiliary and a past participle). These forms differ in aspect, the imperfect being imperfective (i.e., continuous), while the simple past and the compound past being perfective (i.e., completed). For the present tense, a single monolectic tense is generally produced (present indicative mood – *présent*). Similarly, the future tense is predominantly expressed by a monolectic form (future indicative mood – *futur*), although periphrastic forms are also possible (see Table 1).

Materials and method

Participants

Forty-two participants (twenty-one PWA and twenty-one non-brain-damaged participants) took part in our study. This sample size is based on pilot data, which allowed us to determine that this number was sufficient to detect significant differences between groups at an alpha threshold of 0.05 and a statistical power of 0.85.

The 21 PWA (10 women, 11 men) were recruited from hospitals in the French-speaking part of Switzerland (see Appendix A for the individual characteristics). All participants were native French speakers, and three participants were early bilingual (P3: French-German, P13: French-Italian, P20: French-Creole). These three bilingual participants were included in the study because of their excellent command of French (with schooling in French). In addition, all three clinically assessed French as their current dominant language (spoken at home and/or at work). All PWA had chronic aphasia (i.e., stroke onset >6 months) after unilateral left hemisphere stroke. The main manifestation of aphasia had to be difficulties in sentence production, objectified in a picture description task and/or in a syntactic production battery (BEPS; Coulombe et al., 2019). Exclusion criteria included the presence of (i) moderate or severe oral and written comprehension disorders that could impair comprehension of instructions and tasks; (ii) moderate or severe speech disorders; (iii) psychiatric illness other than clinical depression; (iv) alcohol or drug abuse according to DSM-V criteria (American Psychiatric Association, 2013); (v) significant uncorrected vision and/or hearing impairment.

The diagnosis and type of aphasia (fluent versus non-fluent) were obtained from the most recent speech-language pathology reports. They were established with various language tests and by clinical judgment. PWA also completed a picture description task at the beginning of the study (Brookshire & Nicholas, 1993). An independent judge listened to each description and classified participants as having fluent or non-fluent aphasia. An index of fluency, the speech productivity, was also calculated by dividing the pure speaking time (i.e., speaking time without silences) by the total speaking time. This measure has been shown to be one of the most sensitive for discriminating between fluent and non-fluent speech (Park et al., 2011). Descriptive statistics from Park et al. (2011) were then used to characterize speech as fluent (speech productivity > 53%) or non-fluent (<53%). The final type of aphasia retained (fluent versus non-fluent) was based on the greatest consensus between the speech-language pathologist reports and the two analyses of the picture description. Eleven participants were thus classified as non-fluent (with a diagnosis of Broca's aphasia or transcortical motor aphasia) and 10 participants as having fluent aphasia (with a diagnosis of Wernicke, conduction, anomic or transcortical sensory aphasia). Participants with fluent aphasia were older than participants with non-fluent aphasia (Fluent: $M = 70.40$, SD = 8.81; Non-fluent: $M = 59.09$, SD = 13.69; $t(19) = 2.23$, $p = .038$). Education level did not differ between the two PWA sub-groups (Fluent: $M = 13.20$, SD = 3.12; Non-fluent: $M = 12.55$, SD = 3.36; $t(19) = .46$, $p > .05$).

Twenty-one non-brain-damaged (NBD) participants (10 women, 11 men) with no neurological or psychiatric history were also included in the study. Their overall cognitive functioning, assessed by the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005), had to be intact (score >26/30). They were individually matched to the PWA for age (PWA: $M = 64.48$, SD = 12.73; NBD: $M = 64.86$, SD = 12.21; $t(40) = 0.99$, $p > .05$) and education level (PWA: $M = 12.86$, SD = 3.18; NBD: $M = 12.95$, SD = 2.64; $t(40) = 0.106$, $p > .05$).

The local ethics committee (Commission cantonale d'éthique de la recherche sur l'être humain – CER Vaud) approved the study. All participants gave written informed consent prior to enrollment.

Material and procedure

Participants underwent a brief language assessment before performing three tasks assessing time reference and five standardized tests evaluating various cognitive functions. All the tasks were administered to participants over 2 to 3 sessions, in their own homes. The order of administration of the tasks was randomized, and breaks were provided to avoid fatigue effects.

Time reference

Three tasks were used to assess time reference (see Table 2 for examples). In the first task (T1 – verb inflection production), participants were presented with an infinitive verb, followed by a short sentence to complete. The sentence always began with a temporal adverb establishing a temporal frame inducing past (5 years ago), present (now), or future (in a few years). The infinitive verb and the sentence were read aloud to the participants, who had to complete the sentence orally by inflecting the verb in the appropriate tense (past, present, or future).

The second task (T2 – verb inflection selection) was similar in structure to the first (i.e., sentence completion according to a temporal adverb) but differed in response modality. Participants were given three forced-choice answers (target verb in the past, present, or future tense). The infinitive verb and the sentence were read aloud to the participants, who were then asked to point to the verb form corresponding to the temporal frame induced by the sentence.

Finally, in the third task (T3 – adverb selection), participants were presented with sentences containing a verb inflected in the past, present, or future tense but no temporal

Table 2. Examples of the past, present and future conditions of the three tasks.

Task	Past	Present	Future
T1 – Verb inflection production	Manger *Eat* Il y a 5 ans, vous_____ *Five years ago, you* ___ (Target: mangiez/*ate*)	Réunir *Gather* Maintenant, tu______ *Now, you*_____ (Target: réunis/*gather*)	Sortir *Leave* Dans plusieurs années, tu______ *In several years, you*______ (Target: sortiras/*will leave*)
T2 – Verb inflection selection	Manger *Eat* Il y a 5 ans, il_____ *Five years ago, he* _____ (Forced-choice answers:) mange, mangera, mangeait *eats, will eat, ate* (Target: mangeait/*ate*)	Réunir *Gather* Maintenant, il______ *Now, he*_____ (Forced-choice answers:) réunissait, réunit, réunira *gathered, gathers, will gather* (Target: réunit/*gathers*)	Sortir *Leave* Dans plusieurs années, il______ *In several years, he*______ (Forced-choice answers:) sortira, sortait, sort *Will leave, left, leaves* (Target: sortira/*will leave*)
T3 – Adverb selection	Manger *Eat* ______, il mangeait. ______, *he ate.* (Forced-choice answers:) Dans plusieurs années, Maintenant, Il y a 5 ans *In several years, Now, Five years ago* (Target: Il y a 5 ans/*Five years ago*)	Réunir *Gather* ______, il réunit. ______, *he gathers.* (Forced-choice answers:) Maintenant, Il y a 5 ans, Dans plusieurs années, *Now, Five years ago, In several years* (Target: Maintenant/*Now*)	Sortir *Leave* ______, il sortira. ______, *he will leave.* (Forced-choice answers:) Maintenant, Il y a 5 ans, Dans plusieurs années, *Five years ago, Now, In several years* (Target: Dans plusieurs années/*In several years*)

adverb. Three temporal adverbs (five years ago, now, in several years) were presented at the end of the sentence. Participants were asked to choose the temporal adverb corresponding to the temporal frame induced by the inflected verb form.

Each task was administered in writing via a PowerPoint presentation and began with three example items. Forty-eight items per task were then administered, taking approximately 15 minutes per task. The order of stimuli within the tasks was randomized, as was the position of the inflected verbs and adverbs in the selection tasks (T2 and T3). Verbs were controlled for frequency (Lexique database; New et al., 2004), length of the infinitive form (1–4 syllables), and lexical aspect (activities only). Agreement was also controlled in the selection tasks (*il - he*) but manipulated in the verb inflection production task (*tu* or *vous* – 2nd person singular or plural) to avoid automatism and perseveration. Finally, regularity was manipulated in the tasks. In French, verbs can be regular (e.g., *manger-mangeait – eat-ate)*, pseudo-regular (e.g., *réagir-réagissait – react-reacted)*, irregular without root change (e.g., *convaincre-convainquait – convince-convinced)*, and irregular with root change (e.g., *soutenir-soutiendra – support-will support)* (see Bonami et al., 2008; Auclair-Ouellet et al., 2016 for a precise description of regularity in French). Thus, each form of regularity was present in equivalent numbers in each tense. All tasks were pilot-tested with 50 healthy people to validate the stimuli (results of the pilot study: T1: $M = 93.86\%$, $SD = 9.15$; T2: $M = 99.15\%$, $SD = 1.5$; T3: $M = 99.58\%$, $SD = 1.07$).

The time reference tasks and the manipulation of the three tenses were designed to meet our first two objectives (i.e., time reference deficit and dissociations between tenses in PWA). The presence of three different tasks also enabled us to analyze the effect of tasks on time reference performance, our third objective. Finally, the three tasks were chosen based on the Faroqi-Shah (2007) and Faroqi-Shah (2006) studies to explore the pre-phonological origin of time reference deficit and to distinguish, within the DER process, between a deficit in the encoding of diacritic features or in the retrieval of the phonological form corresponding to the selected diacritic features. More specifically, the following profiles could be expected (Faroqi-Shah, 2006):

– An impaired performance on the three tasks would indicate a deficit in the *encoding* of diacritic features. Participants would have difficulty selecting the diacritic features (i.e., present, past, future) conveyed by the inflection or a temporal adverb to produce or select the corresponding phonological form (inflected verb or adverb).

– A worse performance only on the two verb inflection tasks (production and selection) would suggest a deficit in the *retrieval* of the phonological form corresponding to the diacritic features encoded by the temporal adverb. Encoding of the diacritic features would be preserved, as participants could associate a temporal adverb with an inflected verb form (successful adverb selection task).

In addition, analysis of verb regularity in the verb inflection production task should shed light on a possible morpho-phonological origin. A selective deficit on regular verbs would indicate an affixation deficit, whereas an absence of regularity effect or a deficit on irregular verbs would rather suggest a deficit within the DER process (i.e., retrieval of the phonological form).

Cognitive functions

Five neuropsychological tests were also administered to assess the cognitive correlates of time reference, thus meeting our fourth objective. Verbal and non-verbal working memory were assessed with backward span tasks. In the verbal condition, participants were asked to recall in reverse order a sequence of digits of increasing length (WAIS-IV; Wechsler, 2008). In the non-verbal condition, participants had to reproduce in reverse order blocks touched by the examiner (MEM-III; Wechsler, 2001). The maximum spans (i.e., the maximum number of digits recalled or blocks correctly touched) were used as measures of working memory.

Mental flexibility was assessed with the Color Trails Test (CTT; D'Elia et al., 1996). In the first part (CT1), participants had to connect numbers from 1 to 25 in ascending order, presented in pink and yellow circles. In the second part (CT2), numbers from 1 to 25 were presented in duplicate (in pink and yellow). Participants had to connect the numbers in ascending order, alternating colors. An interference index was calculated (CT2 time – CT1 time/CT1 time) and used in the study. The higher the index, the lower the mental flexibility.

For inhibition, the Go/No-Go test (FAB; Dubois et al., 2000) was administered. The participants were asked to tap the table once when the examiner tapped once (Go) and not to tap when the examiner tapped twice (No-Go). The number of correct answers (/10) was calculated.

Finally, the conceptual-semantic notion of temporality was assessed using a new experimental task. A temporal arrow, with indications of past (on the left), present (in the middle), and future (on the right), was placed in front of the participants. Forty labels with temporal adverbs from the past (e.g., last week, recently) or the future (e.g., in 5 years, next weekend) were presented in written and spoken form to the participants, who had to point to the left (past) or right (future) side of the arrow corresponding to the temporal adverb. The score was the number of correct answers.

Data analysis

The first task (T1 – verb inflection production) was recorded. Responses were transcribed and scored binarily (0–1) according to response accuracy. Since temporal adverbs did not convey information about aspect, all verb forms referring to the past were accepted, although the imperfect tense was encouraged in the examples. Paraphasias on verb stems were not penalized, as the focus of the study was on verb inflection. Autocorrections made within 10 seconds were also accepted. In the case of multiple answers, only the last answer given was considered. Errors were then classified into five categories: (i) substitution of one tense for another (e.g., production of the present tense instead of the past tense); (ii) production of a non-inflected form (i.e., an infinitive); (iii) paraphasias on the inflection resulting in an incorrect verb form (e.g., **mangeois* for *mangeais*); (iv) regularization (i.e., applying the inflectional rules for regular verbs to an irregular verb; e.g., *convenirez* for *conviendrez*); (v) others (non-responses, verb changes, agreement errors).

The other two tasks were scored binarily according to response accuracy. Errors were then classified according to the type of substitution (i.e., choose a verb form or adverb in the present [e.g., gathers; now] or future [will gather; in several years] instead of the past [e.g., gathered; five years ago]; ditto for other verb tenses) or as "other" in the case of non-answers.

For all of the study's objectives, we conducted generalized linear mixed models on the dichotomic responses of each participant, using R (R Development Core Team, 2008) and the lme4 package (Bates et al., 2015). Items and participants as random effects and tense or regularity as random slope were included where relevant. Likelihood ratio tests were used to compare the models with the main effect or interaction to a model without it to assess the significance of the main effects and interactions (Pinheiro & Bates, 2000).

For the first objective (tense deficits in people with fluent and non-fluent aphasia), our models included fixed effects for the group (NBDs, fluent and non-fluent) as the independent variable and performance on each task as the dependent variable. For the second and fifth objective, additional models were computed to test the tense effect (past, present, future) and its interaction with aphasia fluency, and the regularity effect (regular, pseudo-regular, irregular without or with stem change) and its interaction with aphasia fluency. These models were carried out on PWA performance only, in conformity with analyses carried out in previous research and as NBD participants performed at the ceiling in the tasks. Moreover, the regularity effect was analyzed only in the verb inflection production task. Post-hoc tests were performed with Tukey correction for multiple comparisons using "lsmeans" package (Lenth, 2016). Finally, to analyze the influence of cognitive variables on the PWA time reference performance (objective 4), several models were performed with the PWA performance on each task as the dependent variable and cognitive scores as the independent variable. The significance level was set at $p < 0.05$ for all the analyses.

Results

Group effects

The mean performance on each task for the three groups is shown in Figure 1(a-c). Likelihood ratio tests revealed a significant effect of group for all the tasks (T1: $\chi^2(2) = 36.652$, $p < .001$, $p < .0001$; T2: $\chi^2(2) = 20.189$, $p < .001$; T3: $\chi^2(2) = 9.9768$, $p < .007$), with better performance in NBD participants than in participants with fluent aphasia (T1: $\beta = 5.192$, SE = 0.62, z = 8.368, $p < .0001$; T2: $\beta = 3.59$, SE = 1.196, z = 3.001, $p = .0076$; T3: $\beta = 3.913$, SE = 1.231, z = 3.179, $p = 0.0042$) and non-fluent aphasia (T1: $\beta = 5.198$, SE = 0.66, z = 7.834, $p < .0001$; T2: $\beta = 4.89$, SE = 1.175, z = 4.159, $p < .0001$; T3: $\beta = 3.302$, SE = 1.203, z = 2.745, $p = .0167$). There was no significant difference between participants with fluent and non-fluent aphasia in all tasks (T1: $\beta = -0.006$, SE = 0.58, z = −0.010, $p = .999$; T2: $\beta = -1.30$, SE = 0.983, z = −1.320, $p = .3839$; T3: $\beta = 0.611$, SE = 0.949, z = 0.644, $p = .7957$).

Tense effects

Regarding tenses, likelihood ratio tests revealed a significant effect of tense for PWA in the three tasks (T1: $\chi^2(2) = 13.82$, $p < .001$; T2: $\chi^2(2) = 9.129$, $p = .01041$; T3: $\chi^2(2) = 8.7229$, $p = 0.01276$). Posthoc analyses showed a worse performance in the past tense than in the present ($\beta = -1.789$, SE = 0.482, z = −3.713, $p = .0006$) and future tenses ($\beta = -1.518$,

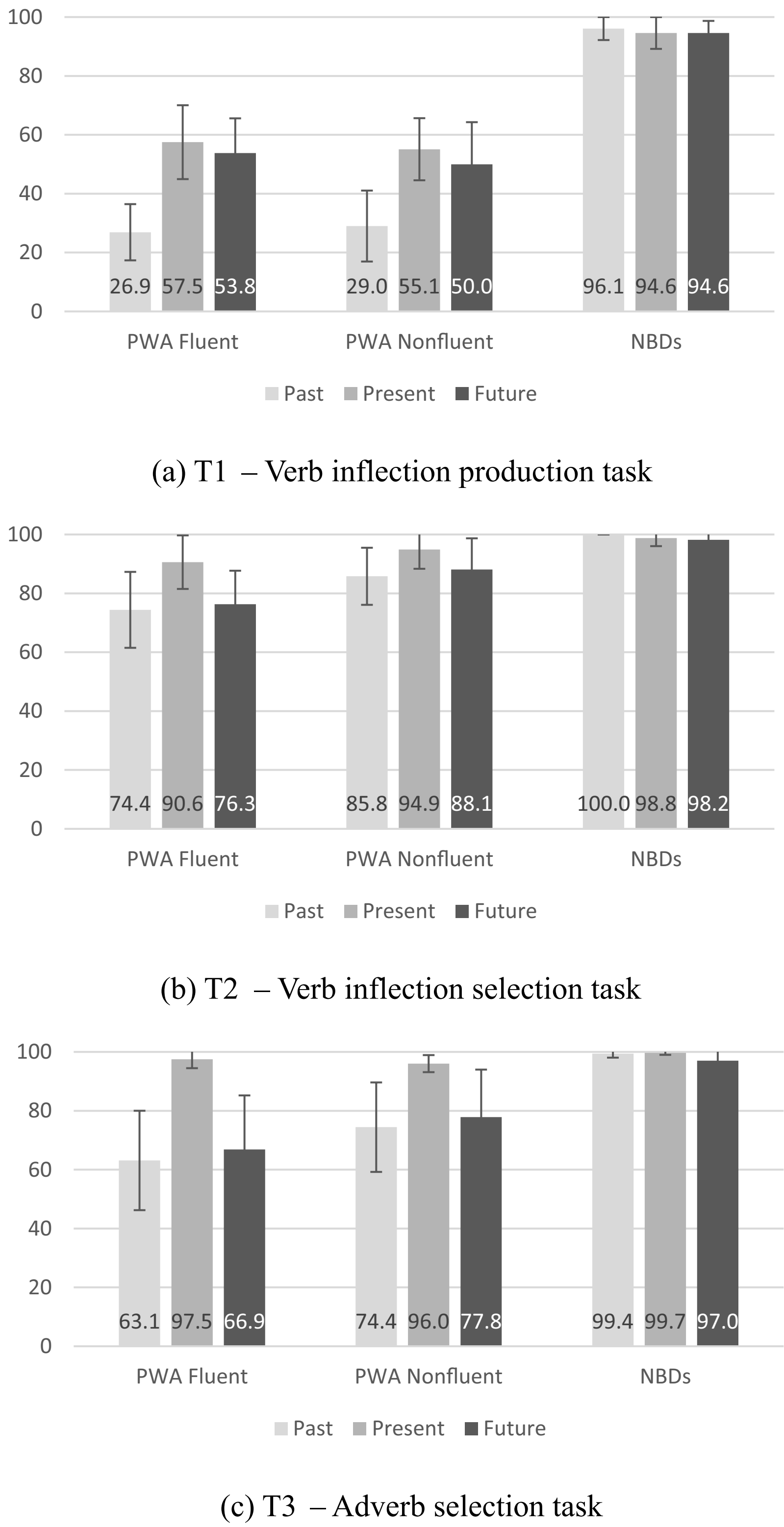

Figure 1. Percentage of correct responses obtained by participants with fluent and non-fluent aphasia and NBD participants for the three tenses (past, present, future) of the verb inflection production (1a), verb inflection selection (1b) and adverb selection (1c) tasks.

SE = 0.541, z = −2.805, *p* = .014) in the verb inflection production task (T1). There was no significant difference between the present and future tenses (β = 0.271, SE = 0.539, z = 0.502, *p* = 0.87). In the two other tasks (T2 – verb inflection selection and T3 – adverb selection), Posthoc analyses revealed no significant differences between past and present (T2: β = −2.936, SE = 1.304, z = −2.251, *p* = 0.0629; T3: β = −2.341, SE = 1.03, z = −2.264, *p* = 0.0609), past and future (T2: β = −0.371, SE = 0.583, z = 0.637, *p* = 0.7996; T3: β = −2.159, SE = 1.17, z = 1.839, *p* = 0.1569), and present and future (T2: β = 2.564, SE = 1.334, z = −1.923, *p* = 0.1322; T3: β = 0.182, SE = 1.70, z = 0.107, *p* = 0.9937). The interactions between group (fluent and non-fluent aphasia) and tense (past, present, future) were not significant in the three tasks (T1: $\chi^2(2) = 0.31$, $p = 0.86$; T2: $\chi^2(2) = 0.7923$, $p = 0.6729$; T3: $\chi^2(2) = 2.8711$, $p = 0.238$).

Error analysis

The percentages of errors in each condition for each task are shown in Tables 3 and 4. The individual scores for the three tasks are given in Appendix B. In the verb inflection production task (T1), participants with fluent and non-fluent aphasia produced a majority of substitutions of one tense for another, particularly in the past tense condition. In this condition, past tense substitutions were predominantly made by future tense forms in participants with fluent aphasia and by present and future tense forms in participants with non-fluent aphasia. Taking all conditions together, the future tense was the most frequent verbal substitution in both groups of PWA.

The pattern of errors between participants with fluent and non-fluent aphasia differed, however, when non-substitution errors were considered. In participants with fluent aphasia, errors consisted mainly of paraphasias and regularizations. Unmarked forms and other responses (e.g., non-responses) were principally observed in participants with non-fluent aphasia.

In the other two tasks of verb inflection selection (T2) and adverb selection (T3), the error pattern was similar in participants with fluent and non-fluent aphasia, with most substitutions from past to future and from future to past.

Table 3. Error types (percentages) in each condition (past, present, future) in the verb inflection production task (T1) for the participants with fluent and non-fluent aphasia.

Target form →	Past		Present		Future		Total	
Produced form ↓	Fluent	Nonfluent	Fluent	Nonfluent	Fluent	Nonfluent	Fluent	Nonfluent
Substitutions								
Past	–	–	1.56%	1.38%	4.28%	2.07%	5.84%	3.45%
Present	2.72%	8.62%	–	–	2.72%	4.83%	5.44%	13.45%
Future	23.74%	9.66%	14.79%	5.86%	–	–-	38.53%	15.52%
Other	8.56%	5.86%	1.56%	2.41%	3.50%	1.72%	13.62%	9.99%
Unclassifiable	0.78%	0%	0%	0%	0%	0%	0.78%	0%
Total	35.80%	24.14%	17.90%	9.65%	10.51%	8.62%	64.21%	42.41%
Unmarked	1.17%	6.90%	1.17%	8.62%	0.78%	6.55%	3.12%	22.07%
Paraphasia	6.23%	3.79%	2.33%	3.10%	6.23%	6.55%	14.79%	13.44%
Regularization	0.39%	0%	2.33%	0.34%	6.61%	1.38%	9.33%	1.72%
Other	1.17%	7.93%	2.72%	5.52%	4.67%	6.90%	8.56%	20.35%

Table 4. Error types (percentages) in each condition (past, present, future) in the verb inflection selection task (T2) and the adverb selection task (T3) for the participants with fluent and non-fluent aphasia.

Target form →	Past		Present		Future	
Substitutions ↓	Fluent	Nonfluent	Fluent	Nonfluent	Fluent	Nonfluent
Inflection selection task						
Past	–	–	2.13%	5.45%	38.30%	36.36%
Present	1.06%	1.82%	–	–	1.06%	1.82%
Future	42.55%	43.64%	13.83%	10.91%	–	–
Other (NA)	0%	0%	0%	0%	1.06%	0%
Adverb selection task						
Past	–	–	1.72%	5.49%	36.21%	30.77%
Present	10.34%	15.38%	–	–	9.48%	12.09%
Future	40.52%	34.07%	1.72%	2.20%	–	–
Other (NA)	0%	0%	0%	0%	0%	0%

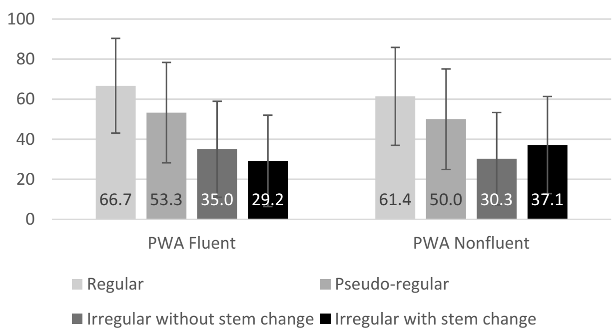

Figure 2. Percentage of correct responses obtained by participants with fluent and non-fluent aphasia for the four regularity conditions (regular, pseudo-regular, irregular without and with stem change) of the verb inflection production task.

Regularity effect

The mean performance in each regularity condition of the verb inflection production task for the two groups with aphasia is shown in Figure 2. The likelihood ratio tests revealed a significant effect of regularity for PWA ($\chi^2(3) = 17.174$, $p < .001$). Posthoc analyses showed better performance for the regular verbs than for the irregular verbs without stem change (β = 1.893, SE = 0.500, z = 3.788, $p = .0009$) and with stem change (β = 1.790, SE = 0.497, z = 3.604, $p = .0018$). There was no significant difference between the regulars and pseudo-regular verbs (β = 0.721, SE = 0.490, z = 1.470, $p = 0.46$), the pseudo-regular verbs and the irregular verbs without stem change (β = 1.172, SE = 0.495, z = 2.365, $p = 0.08$) or with stem change (β = 1.069, SE = 0.493, z = 2.170, $p = 0.13$), and the irregular verbs with or without stem change (β = 0.103, SE = 0.498, z = 0.206, $p = 0.99$). The interaction between group (fluent and non-fluent aphasia) and regularity (regular, pseudo-regular, irregular with or without stem change) was not significant ($\chi^2(3) = 3.774$, $p = 0.29$).

Table 5. Performance of participants with fluent and non-fluent aphasia and of the non-brain-damaged (NBD) participants on the tests assessing cognitive functions.

	PWA Fluent		PWA Nonfluent		NBD	
	Mean	SD	Mean	SD	Mean	SD
Executive functions						
Verbal working memory (span backward/8)	2.50	0.71	2.55	0.69	4.62	1.32
Non-verbal working memory (span backward/9)	4.40	0.84	4.91	1.14	-	-
Mental flexibility (index CTT)	1.20	0.61	1.16	0.47	-	-
Inhibition (Go/No-Go/10)	9.10	1.52	9.45	1.51	-	-
Temporality						
Time arrow (/40)	37.30	2.00	35.73	4.92	39.43	0.93

Table 6. Likelihood ratio test results for each cognitive predictor in the three tasks.

	Inflection production		Inflection selection		Adverb selection	
Model tense + predictor	LRT	p-value	LRT	p-value	LRT	p-value
Verbal working memory (span)	$\chi^2(1) = 3.837$	***.050***	$\chi^2(1) = 3.587$	***.058***	$\chi^2(1) = 4.603$	**.032**
Non-verbal working memory (span)	$\chi^2(1) = 1.448$	.229	$\chi^2(1) = 9.240$	**.002**	$\chi^2(1) = 7.463$	**.006**
Mental flexibility (index CTT)	$\chi^2(1) = 1.481$	.223	$\chi^2(1) = 0.015$	.904	$\chi^2(1) = 3.193$	.074
Inhibition (Go-NoGo;/10)	$\chi^2(1) = 0.188$	.664	$\chi^2(1) = 0.002$	.961	$\chi^2(1) = 2.394$	.122
Time arrow (/40)	$\chi^2(1) = 5.281$	**.022**	$\chi^2(1) = 3.366$	*.067*	$(\chi^2(1) = 7.538$	**.006**

Bold = significant; italics = marginally significant.

Cognitive correlates

The performance of participants with fluent and non-fluent aphasia on each neuropsychological test is presented in Table 5. Likelihood ratio test results for each cognitive predictor are given in Table 6. The results revealed a significant or marginally significant effect of verbal working memory on performance in the three time-reference tasks, as well as a significant effect of non-verbal working memory in the inflection (T2) and adverb (T3) selection tasks: the better the verbal and non-verbal working memory scores, the better the time reference scores. A significant or marginally significant positive effect of performance on the temporality task (arrow) was also observed in the three tasks. There was no significant effect of mental flexibility and inhibition on the time reference tasks.

Discussion

The present study was designed to answer five questions:

(1) Is time reference impaired in French speakers with fluent and non-fluent aphasia?
(2) Is one tense more impaired in French speakers with fluent and non-fluent aphasia?
(3) Does task type influence performance in time reference and tense dissociations in PWA?
(4) What are the cognitive predictors underlying time reference in PWA?

(5) What is the origin (pre-phonological, morpho-phonological) of the time reference deficit in PWA?

To answer these questions, we administered three tasks assessing time reference (verb inflection production, verb inflection selection, and adverb selection) and five cognitive tests to 21 individuals with fluent and non-fluent aphasia and 21 matched NBD participants.

The results provided a positive answer to the first question, as participants with fluent and non-fluent aphasia had a worse performance than NBD subjects on all three tasks. These findings are consistent with previous studies that have demonstrated time reference deficits in PWA speaking different languages, including Romance languages close to French (Fyndanis et al., 2023; Fyndanis, Arcara, Capasso, et al., 2018; Martínez-Ferreiro & Bastiaanse, 2013).

Interestingly, people with fluent aphasia performed similarly to people with non-fluent aphasia. A recent meta-analysis (Cordonier et al., 2024) showed slightly lower performance in people with non-fluent aphasia than in those with fluent aphasia. However, the authors reported that the small number of participants with fluent aphasia included in the meta-analysis was a limitation. In addition, the performance of this group of participants was more heterogeneous than that of the non-fluent group (see standard deviations in Figure 2 of the meta-analysis). Studies that have directly compared individuals with fluent and non-fluent aphasia have produced conflicting results, with some studies (Dragoy & Bastiaanse, 2013) finding comparable performance and others (Bos & Bastiaanse, 2014) finding lower performance in people with non-fluent aphasia. These contradictory results suggest that other neurological factors, such as the extent of the lesion or the severity of the aphasia, could have a greater influence on general performance in time reference than the type of aphasia (Akinina et al., 2021; Caplan et al., 2016; Wilson & Saygın, 2004). Further studies are needed to clarify the neurological factors influencing tense production.

Concerning our second research question on the difference between tenses, the results of the first task (verb inflection production) revealed poorer performance in the past than in the present and future. These results are in line with previous study findings in other languages (e.g., Dragoy & Bastiaanse, 2013; Jonkers & de Bruin, 2009; Rofes et al., 2014). They also support the PADILIH (Bastiaanse, 2013; Bastiaanse et al., 2011), which argues that the past tense would be more difficult to produce because of the discourse linking that must be established between the speech time and the event time. This selective impairment of the past would affect people with fluent and non-fluent aphasia alike (Bos & Bastiaanse, 2014; Cordonier et al., 2024), which is confirmed by our results.

Interestingly, the worse performances in the past tense were not objectified in the other two selection tasks. This result thus confirms our third hypothesis of a task-type effect. It also corroborates the findings of Faroqi-Shah and Friedman (2015), who observed a tense effect only in a priming task (TART) but not in forced-choice sentence completion tasks. Kok et al. (2007) suggested that forced-choice verb selection tasks should be considered comprehension rather than production tasks. However, studies that have analyzed time reference both in production and comprehension (Abuom & Bastiaanse, 2013; Bastiaanse et al., 2011; Jonkers & de Bruin, 2009) found a similar error pattern (past < non-past), supporting PADILIH's claim that past selective impairment also occurs in comprehension. Therefore, the dimension assessed by the tasks (comprehension versus production) cannot explain the lack of dissociation observed in the forced-choice tasks.

Another explanatory hypothesis is that the dissociation between tenses would be only apparent in complex tasks, such as in our verb inflection production task (El Ouardi, 2021; Nerantzini et al., 2020). Qualitative analysis of performance on the three tasks revealed poorer performance of PWA on the verb inflection production task than on the verb inflection selection and adverb selection tasks. These results are in line with the meta-analyses by Faroqi-Shah and Friedman (2015) and Cordonier et al. (2024), who reported better performance in forced-choice tasks than in production tasks. We could hypothesize that complex tasks (e.g., verb inflection production) would challenge PWA with limited cognitive resources, even more in past conditions that involve a cumulative cognitive load linked to the task and discourse linking. The analysis of cognitive predictors (fourth research question) partially confirms this hypothesis.

Indeed, our results demonstrated a significant or marginally significant link between verbal working memory and our three tasks assessing time reference. This link between time reference and verbal working memory has already been demonstrated in elderly people (Fyndanis & Themistocleous, 2019; Fyndanis et al., 2022), people with Alzheimer's disease (Fyndanis, Arfani, et al., 2018) and PWA (Auclair-Ouellet et al., 2019; Fyndanis, Arcara, Christidou, et al., 2018). However, our results also suggest that the involvement of verbal working memory may be independent of task type. According to the Interpretable Feature's Impairment Hypothesis (IFIH; Fyndanis et al., 2012), tense would be costly in processing resources, as it would bear interpretable features that contribute to semantic interpretation and involve processing and integrating information at the grammatical and conceptual levels (Kok et al., 2007). These interpretable features are involved in all tasks assessing time reference. Consequently, people with limited resources and/or reduced verbal working memory would have difficulties in all tense tasks.

To take the analysis further, it would have been relevant to analyze whether cognitive functions, and especially verbal working memory, were involved differently according to the type of aphasia and tense. This was not possible in the present study. Indeed, statistical models with interactions between cognitive predictors and group (fluent vs. non-fluent aphasia) or between cognitive predictors and tense (past, present, and future) would have lacked statistical power and risked type II errors. However, it would be interesting to conduct such analyses in future studies with larger cohorts to clarify whether past tense is cognitively more demanding and whether different cognitive processes underpin the time reference deficit of people with fluent and non-fluent aphasia.

Unlike verbal working memory, non-verbal working memory was associated only with the verb inflection selection (T2) and adverb selection (T3) tasks but not with the verb inflection production task (T1). To our knowledge, only one study (Fyndanis et al., 2022) has analyzed the link between verbal, non-verbal working memory and time reference in healthy participants. Their results showed a main effect of verbal working memory, but not non-verbal working memory, on their tense production task. They concluded that morphosyntactic production relies on domain-specific (i.e., verbal) memory resources. Their study used a tense transformation task, which involves processes quite similar to those involved in our verb inflection production task (in particular, phonological form retrieval). Our results from the verb inflection production task are thus in line with this study and suggest that verbal (but not non-verbal) working memory capacities are required to retrieve and produce the phonological form corresponding to a given temporal frame. However, how can we explain the role of non-verbal working memory in verb inflection selection and adverb selection tasks?

Since Tasks 1 and 2 differed only in the response modalities (the other parameters being similar between these tasks), one hypothesis is based on the layout of the forced-choice answers. Indeed, the placement of the forced-choice answers was randomized to avoid habituation or perseveration. Verbs or adverbs referring to the past or the future were thus randomly placed to the left, middle, or right. As a result, this placement could conflict with our "mental timeline", with the past generally located on the left and the future on the right (Bonato et al., 2012). This reasoning is analogous to that of numbers, which would be represented along a mental number line. Several studies (e.g., Herrera et al., 2008) have thus demonstrated a link between non-verbal working memory and the spatial representation of numbers (e.g., the SNARC effect). In our study's forced-choice tasks, non-verbal working memory could have been called upon to simultaneously process the mental representation of time and the temporal notions conveyed by verbs and adverbs randomly placed on the PowerPoint. However, it would be relevant to repeat our results with more participants or compare them with forced-choice tasks respecting the spatial timeline to validate this hypothesis.

Regarding inhibition and flexibility, our results showed no association with the time reference assessed in our three tasks. To date, no study has analyzed these links in PWA. In the context of neurodegenerative diseases, a recent study (Schaffner et al., 2024) has, for the first time, demonstrated a link between flexibility, inhibition, and time reference in people with Alzheimer's disease, suggesting that these processes may be involved in the production of tense. In the context of our study, it is possible that the executive tasks used were not sufficiently sensitive to reveal such associations.

The selection of executive tasks for PWA is complex. The tasks commonly used are diverse and often involve non-executive processes, particularly linguistic ones, which can cause significant difficulties for PWA (Tessaro et al., 2024). The Go/No-Go task was chosen in our study to limit this linguistic load. However, this task proved too simple, with 14 participants performing at ceiling level. Moreover, it did not include a time measure, which could provide a more precise analysis of executive deficits (Purdy, 2002). Therefore, using more complex non-verbal timed tasks, such as a non-verbal Stroop task (e.g., Zakariás et al., 2013) or the Go/No-Go task from the TAP (Tests d'Evaluation de l'Attention; Zimmerman & Fimm, 2012), would be valuable for examining the implication of inhibition in time reference.

In addition, tasks that assess the same executive process may involve different mechanisms (Van der Linden et al., 2014). For example, while Stroop or Go/No-Go tasks involve inhibiting a dominant response, other tasks, such as the Flanker task (Eriksen & Eriksen, 1974), involve resistance to interference. This mechanism might be particularly engaged in forced-choice response tasks, such as in our Tasks 2 and 3. The same reasoning applies to flexibility. In their study, Schaffner et al. (2024) observed an effect of flexibility on the verb inflection ability of patients with Alzheimer's disease. Interestingly, this effect was observed when flexibility was measured by the Category

Switching condition of the Verbal Fluency test (Delis et al., 2001) but not by the Trail Making Test (Tombaugh, 2004). Consequently, other flexibility tasks, such as the Wisconsin Card Sorting Test (Berg, 1948), often used with PWA (Fonseca et al., 2017), might better reflect the possible impact of flexibility on time reference.

Finally, our results also showed a significant or marginally significant relationship between the three time-reference tasks and the temporality assessment task (arrow) specifically designed for this study. These results are interesting because they demonstrate that the PWA difficulties with tense could also stem from a deficit in associating a notion of temporality (past or future) with temporal adverbs. In the context of Alzheimer's disease, it has been shown that conceptual difficulties in perceiving and "traveling" in time can manifest themselves in time reference disorders (Irish et al., 2016). In aphasia, these difficulties are probably more semantic, linked to the lexicon of temporality. More studies are needed, however, to clarify this conceptual-semantic origin.

Lastly, our fifth research question aimed to explore the origins of the time reference deficits, distinguishing between a pre-phonological origin (i.e., a deficit in encoding diacritic features or in retrieving the phonological form corresponding to the selected diacritic features – DER process) and a morpho-phonological origin. (i.e., an affixation deficit). To this end, we analyzed performance in the three tasks, verb regularity in the verb inflection production task, and error patterns.

The impaired performance in the three tasks, both in participants with fluent and non-fluent aphasia, suggests a pre-phonological origin and, more specifically, a deficit in encoding diacritic features. Indeed, PWA appear to have difficulty encoding diacritic features conveyed by a temporal adverb or verb inflection to then produce or select the correct phonological form or adverb. Our results, therefore, contradict those of Faroqi-Shah (2006), who concluded that phonological form retrieval rather than diacritic features encoding was affected. Her reasoning was based on the high accuracy obtained by PWA in an adverb selection task and the low accuracy obtained in an inflected verb selection task. However, it is interesting to note that the high accuracy obtained by the PWA in her adverb selection task corresponded to 80%, which is relatively similar to the percentages obtained by the PWA in our study. In addition, Faroqi-Shah's (2006) study included only five participants with aphasia, and the adverbs used in some of her stimuli – *everyday, yesterday, last year* – did not refer to the future, unlike in our study. Yet, the analysis of our participants' errors showed that past and future adverbs are frequently confused. Consequently, we argue that PWA's time reference deficits would originate *already* at the level of diacritic features encoding. However, this "high-level" origin does not rule out impairments at subsequent levels.

Indeed, the qualitatively poorer performance of people with fluent and non-fluent aphasia in the verb inflection production task suggests that the retrieval of the phonological form corresponding to the selected diacritic features might also be problematic for PWA. This hypothesis is supported by the analysis of regularity, which showed worse performances for irregular than regular verbs in both participants with fluent and non-fluent aphasia. These worse performances for irregular verbs, which do not require affixation processes, and regularization errors (i.e., applying an affixation rule to an irregular verb) also suggest that a morpho-phonological origin is less likely, although it cannot be completely ruled out. Indeed, Faroqi-Shah (2007), p. 144) argued that "differences between overall impairments of regular and irregular verbs in the presence of a DER deficit may occur due to superimposing phonological or lexical retrieval deficits. What is incompatible with a DER deficit is normal performance on only either regularly or irregularly inflected tensed verbs". The percentage of correct answers for regular verbs in PWA (around 60%) suggests that these verbs are also impaired, although to a lesser extent than irregular verbs.

Similarly, although participants with fluent and non-fluent aphasia showed similar patterns across tasks, it is possible that the degree of impairment or the exact origin of the deficits may differ slightly between these two groups. Indeed, our study concurs with the findings of previous studies, which have found a different error pattern between individuals with fluent and non-fluent aphasia (Bos & Bastiaanse, 2014; Dragoy & Bastiaanse, 2013; Jonkers & de Bruin, 2009). In the first task of our study, participants with non-fluent aphasia produced most substitutions of one tense for another, with an equally high proportion of substitutions by present and future tenses. These surprising results run counter to previous studies, which found a majority of substitutions by the present tense, the most frequent verb form (Bastiaanse et al., 2011; Martínez-Ferreiro & Bastiaanse, 2013). The high presence of future tense substitutions may be explained by the morphology of French, which, unlike other languages, has a monolectic future tense. Moreover, the morphological structure of the future tense is relatively easy in French since it consists in adding an inflection (*-ras*) to the infinitive. In addition to substitution errors, people with non-fluent aphasia also produced numerous unmarked forms and non-responses. This pattern of errors is consistent with agrammatism and, more precisely, with the telegraphic style typically described in non-fluent aphasia (Kolk et al., 2003). It also partly supports Bos and Bastiaanse's (2014) idea that grammatical encoding may be particularly problematic for participants with non-fluent aphasia, leading them to produce grammatically simple forms. Regarding participants with fluent aphasia, our results revealed a majority of substitutions by the future, paraphasias, and regularizations. These error patterns seem to suggest a multiple origin, namely grammatical encoding (for substitution errors) and lexical retrieval (for paraphasia and regularization errors).

Interestingly, the error patterns of participants with fluent and non-fluent aphasia were similar in the two simpler forced-choice response tasks (T2 and T3). Dragoy and Bastiaanse (2013) also observed discrepancies in errors between their two groups only in the more complex conditions. These findings again suggest that cognitively complex tasks, such as the verb inflection production task in our study, are probably more likely to reveal more subtle deficits and, thus, differences between participants with fluent and non-fluent aphasia.

Finally, it is worth noting that the origin of the difficulties may vary between individuals. In a recent study, Fyndanis et al. (2023) attempted to distinguish within the DER process between an origin in the diacritic features encoding or phonological form retrieval. To do so, they used two different tasks: a transformation task, which requires encoding diacritic features (e.g., past) that differ from the source sentence and retrieving the phonological form corresponding to the diacritic features; and a transposition task (i.e., the TART), which involves only the phonological form retrieval process. Indeed, as the time reference remains similar between the source and target sentences, the participant does not have to encode the diacritic features. The authors hypothesized that worse performances on the transformation task may indicate an encoding diacritic features deficit; poor performance on both tasks may suggest a deficit in retrieving the phonological form corresponding to the diacritic features; worse performances on the transposition task would be unrelated to diacritic features encoding and phonological form retrieval deficits. Their analyses revealed various intra-individual dissociations, which they associated with different origins.

Limitations

Several limitations of the present study need to be addressed. Firstly, we included three bilingual participants in our sample of PWA. This choice was motivated by the large proportion of bilingual individuals (over half the world's population; Grosjean, 2021) and by the excellent command of French demonstrated by these participants (i.e., early bilingualism, schooling in French, language spoken in the family and/or at work). However, little is known about the influence of bilingualism on time reference. One study (Abuom & Bastiaanse, 2013) included Swahili-English bilingual participants and showed a time reference deficit in both languages, despite slightly better performance in Swahili, and comparable deficit patterns in both languages (i.e., past < non-past) in their PWA. The strong correlation between the two languages led the authors to conclude that a single central deficit might underlie the overall performance patterns. Therefore, it is likely that the bilingualism of our three participants did not impact our results. However, more studies, including different languages and different types of bilingualism, are needed to confirm this. Secondly, as suggested earlier, it is possible that the executive tasks chosen, particularly for inhibition and flexibility, were not sufficiently fine-tuned to highlight the role of these predictors in time reference. Future studies on time reference that include finer-grained measures of inhibition and flexibility, such as the non-verbal Stroop task, a computerized Go/No-go task or the Flanker task for inhibition, and the Wisconsin Card Sorting Test for flexibility, could better clarify the possible implication of these cognitive functions.

Conclusion

In conclusion, our study demonstrated, for the first time, time reference deficits in French speakers with fluent and non-fluent aphasia. If the past might be more difficult for PWA, this pattern seems to be driven by the type of task used. Difficulties in verbal and non-verbal working memory, and at the conceptual-semantic level, could also interfere with time reference. Finally, our study also clarified the origin of the difficulties, suggesting that a deficit in encoding diacritic features would be the most likely. However, it is important to note that the origin of these difficulties is likely to be multiple and to vary from one individual to another. This issue of performance heterogeneity will be addressed in Part II of our article (Cordonier et al., in press).

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Data availability statement

The data that support the findings of this study are available from the corresponding author, NC, upon reasonable request.

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Appendix A. Sociodemographic and clinical data of the participants with aphasia

Participant	Gender	Age	Education (years)	Handedness	Diagnosis	Aetiology and lesion site	Time post-onset (months)
P1	M	57	15	Left	Broca	Ischemic CVA – left MCA	166
P2	F	60	15	Right	Broca	Ischemic CVA – left MCA	73
P3	M	80	15	Right	Conduction	Hemorrhagic CVA – left fronto-temporo-parietal	92
P4	M	76	11	Right	Conduction	Ischemic CVA – left MCA	61
P5	F	68	19	Right	Wernicke	Ischemic CVA with hemorrhagic transformation – left MCA, temporo-parietal	35
P6	M	72	9	Right	Broca	Ischemic CVA – left ACA and MCA, basal ganglia	6
P7	M	50	18	Right	Broca	Ischemic CVA with hemorrhagic transformation – left ACA and MCA, fronto-parietal	7
P8	M	76	12	Right	Wernicke	Ischemic CVA – left parieto-temporo-occipital	6
P9	M	61	13	Right	Anomic	Ischemic CVA – left MCA (putamen, insula, caudate nucleus, temporal)	6
P10	F	78	9	Right	Conduction	Ischemic CVA with hemorrhagic transformation – left MCA, fronto-parieto-occipital	7
P11	M	47	14	Right	Motor transcortical	Ischemic CVA with hemorrhagic transformation – left PCA, occipital	26
P12	F	39	17	Right	Broca	Ischemic CVA with hemorrhagic transformation – left MCA	28
P13	M	66	9	Right	Broca	Ischemic CVA with hemorrhagic transformation – left ACA and MC, basal ganglia	10
P14	F	78	10	Right	Conduction	Ischemic CVA – left cortico-subcortical of the supra-marginal gyrus and post-central	6
P15	F	78	9	Right	Broca	Left CVA	281
P16	M	65	14	Right	Conduction	Ischemic CVA – left MCA, fronto-temporo-parietal, insula	37
P17	F	63	11	Right	Broca	Ischemic CVA – frontal	105
P18	F	77	10	Right	Broca	Ischemic CVA – left MCA	6

(*Continued*)

(Continued).

Participant	Gender	Age	Education (years)	Handedness	Diagnosis	Aetiology and lesion site	Time post-onset (months)
P19	F	69	17	Right	Sensorial transcortical	Ischemic CVA – left MCA and PCA	45
P20	F	41	11	Right	Broca	Ischemic CVA with hemorrhagic transformation – left MCA	37
P21	M	53	12	Right	Conduction	Ischemic CVA – left MCA, fronto-temporo-parietal, capsulo-caudo-lenticular nucleus	5

ACA = anterior cerebral artery ; CVA = Cerebrovascular Accident; MCA = middle cerebral artery; PCA = posterior cerebral artery.

Appendix B. Individual scores for the three conditions (past, present and future) of the three tasks assessing time reference

	T1 – Verb inflection production			T2 – Verb inflection selection			T3 – Adverb selection		
Participant	Past	Present	Future	Past	Present	Future	Past	Present	Future
P1	3	8	11	6	16	13	11	14	10
P2	7	12	13	15	16	16	16	16	16
P3	1	1	12	6	9	15	13	13	11
P4	1	14	14	15	16	12	9	16	10
P5	2	8	6	16	16	16	16	16	16
P6	6	10	12	16	16	16	16	16	16
P7	0	5	1	15	16	16	15	16	16
P8	1	7	3	7	16	5	0	15	0
P9	7	12	10	16	16	15	16	16	16
P10	9	12	12	15	15	15	7	16	13
P11	13	14	14	16	15	16	16	16	16
P12	8	13	9	16	16	16	16	16	16
P13	5	11	8	13	16	15	5	16	7
P14	7	10	9	11	9	9	6	16	4
P15	0	5	3	11	15	7	4	14	4
P16	5	10	3	16	16	9	16	16	16
P17	2	5	10	16	16	16	16	16	16
P18	5	8	5	12	9	8	7	15	4
P19	3	5	10	9	16	15	12	16	16
P20	2	6	2	15	16	16	9	14	16
P21	7	13	7	8	16	11	6	16	5

The maximum score is 16 for each condition, with a maximum score of 48 per task.