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Time reference in French-speaking people with fluent and non-fluent aphasia (part II): a cluster analysis

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ABSTRACT

Background: Tense production is often impaired in people with aphasia (PWA). Interestingly, the literature suggests that not all tenses are affected in the same way, although the pattern of dissociation is still debated in the literature. The heterogeneity of tense production deficits in PWA might partly explain this lack of consensus in the literature. While this heterogeneity has been demonstrated by descriptive statistics or double dissociations in several studies, no study has used cluster analyses to highlight the main patterns of tense dissociation. Furthermore, the factors underlying this heterogeneity have been little explored.

Aims: Our study aimed to use cluster analyses on tense production performance to (1) identify the main patterns of dissociation between tenses in PWA and (2) explore the clinical (aphasia type and severity) and cognitive (executive disorders and temporality) factors that may underlie these patterns.

Methods & procedures: Twenty-one French-speaking participants with fluent and non-fluent aphasia completed a verb inflection production task, as well as language and cognitive tests. Cluster analyses were performed on the differences in performance between the tenses on the verb inflection production task. Generalized linear mixed models and nonparametric statistics were used to analyze the effect of tense and its interaction with the clusters, and to compare the clusters on the clinical and cognitive variables.

Outcomes & results: Cluster analyses revealed two main clusters, one with worse performances in the past and future than in the present (PWA_1 – 70% of the PWA), and the other with worse performances in the past and present than in the future (PWA_2 – 30%). The type and severity of aphasia, and cognitive test performance did not differ between the two clusters. On the other hand,

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the PWA_2 cluster had a longer time post-onset than the PWA_1 cluster.

Conclusions: Our results confirm the heterogeneity of verb inflection deficits in PWA. They suggest that most PWA would have difficulties with past and future tenses, questioning the presence of discourse linking in these two tenses. However, a minority of PWA, who are clinically and cognitively indistinguishable from the others, do not follow this pattern. Adopting the strategy of producing a morphologically simple tense in French – future – could explain the high performance in the future tense and the errors in substituting other tenses with the future in this subgroup. Finally, the clinical and research implications of this heterogeneity, in relation to therapies and the lack of consensus in the literature, are discussed.

Introduction

Every day, we travel through time mentally, whether discussing the events of the day just gone by or our holiday plans. This mental travel is materialized in discourse through time reference, the linguistic expression of time. Indeed, in many languages, verb inflections and temporal adverbs are used to specify whether the event being narrated takes place before (past), during (present), or after (future) the speech time (Grisot, 2018; Reichenbach, 1947). Tenses are thus essential to communication, structuring our discourse and increasing its informativeness.

In fluent and non-fluent aphasia, the production of tenses is often impaired, contributing to difficulties in communicating (Bastiaanse et al., 2006). Interestingly, not all tenses seem to be affected in the same way in people with aphasia (PWA). According to the PAST Discourse Linking Hypothesis (PADILIH; Bastiaanse et al., 2011), the past tenses may be more impaired than the present and future tenses because of the discourse linking that must be established between the speech time and the event time, which is prior. This discourse linking is costly in terms of processing resources. In the present tense, this discourse linking is unnecessary since the speech time coincides with the event time. The same applies to the future, considered a subclass of the present insofar as the event has not yet taken place. However, this hypothesis is not unanimously accepted in the literature.

Indeed, while several studies have found worse performances in the past compared to the present and/or future in PWA (Bastiaanse, 2013; Bos & Bastiaanse, 2014; Dragoy & Bastiaanse, 2013; Jonkers & de Bruin, 2009; Martínez-Ferreiro & Bastiaanse, 2013; Yarbay Duman & Bastiaanse, 2009; see Cordonier et al., 2024 for a review), other studies have found no dissociation between tenses (Burchert et al., 2005; Clahsen & Ali, 2009). Some studies have also found similar impairments in the past and the future tenses, thus challenging the idea of the future as a subclass of the present (Fyndanis, Arcara, Capasso, et al., 2018; Koukouloti & Bastiaanse, 2020).

There are several possible explanations for this lack of consensus regarding tense dissociation. Some explanatory hypotheses, such as the effects of tasks and participants' cognitive resources on performance and tense dissociations, were explored in Part I of our article (Cordonier & Fossard, *in press*). This first part showed that participants with fluent

and non-fluent aphasia performed worse in the past tense than in the present and future tenses in a task involving completing sentences with an inflected verb according to a temporal adverb (e.g., *leave – now you ___* (expected response: *leave*)). In contrast, the differences between tenses were statistically not significant in two other forced-choice tasks requiring the completion of sentences with an inflected verb (e.g., *leave – now, he ___*; forced-choice answers: *leaves, left, will leave*) or a temporal adverb (e.g., *___, he leaves*; forced-choice answers: *five years ago, now, in several years*). These findings thus suggested that a poorer performance in the past tenses might be observed only in complex tasks, such as sentence completion tasks based on a temporal adverb or transposition tasks (e.g., *in this picture, the man just ate an apple → peel – in this second picture, the man just ... an apple*; expected answer: *peeled*; see also Faroqi-Shah & Friedman, 2015). This cognitive cost of the task would be added to the cognitive cost of the past tense discourse linking and could adversely affect participants with limited cognitive resources (typically poor verbal working memory). In the present article (Part II), we aimed to explore another explanatory hypothesis: PWA heterogeneity.

Performance heterogeneity in PWA

Performance heterogeneity in PWA is important to consider for two main reasons. Firstly, it is likely to explain some of the inconsistencies in the literature. Indeed, most studies used group analyses, the results of which were influenced by the dominant profiles. For example, if some participants performed worse in the past condition and others in the future condition, group analyses may be biased by the number of participants corresponding to each case. Most participants with selective difficulties in the past will thus skew the results of the study in favor of poorer performance in the past tenses compared to other tenses. Conversely, a large number of participants with future-selective difficulties could lead to a lack of dissociation between past and future or to more severe impairment in the future than in the past.

Secondly, it is generally accepted that performance heterogeneity in PWA could reflect different origins of the difficulties (Bos & Bastiaanse, 2014). Therefore, individual analyses are essential to shed light on the origin of a participant's tense production difficulties. Identifying this origin then has fundamental clinical implications, allowing the development of targeted therapeutic goals (Ericson et al., 2023).

In the title of his article, Kolk (2007) stated that "Variability is the hallmark of aphasic behavior: Grammatical behaviour is no exception". Regarding tense production performance, inter-individual variability is well-known and has been demonstrated in several ways. Some studies have thus used qualitative analyses to describe the ceiling performance achieved by some of their participants with aphasia in different tenses – past, present and/or future (Abuom & Bastiaanse, 2013; El Ouardi, 2021; Faroqi-Shah & Friedman, 2015; Faroqi-Shah & Thompson, 2004; Koukouliti & Bastiaanse, 2020). Scores below chance or below two standard deviations in each tense were also used to identify intra-individual dissociations in PWA in one study (Burchert et al., 2005). Finally, a few studies have used statistical analyses (e.g., binomial tests or Fisher's exact tests) to highlight double dissociations of tenses in their participants with aphasia (Bastiaanse et al.,

2011; Fyndanis et al., 2023; Fyndanis, Arcara, Christidou, et al., 2018; Kok et al., 2007; Koukoulioti et al., 2020). These analyses have shown different, often opposite, patterns of dissociation in their participants (e.g., past < future for some participants, future < past for others). However, to our knowledge, no study has used a statistical method well-suited for studying performance heterogeneity: cluster analyses.

Cluster analyses

Cluster analyses involve grouping entities that share similarities on a given variable to obtain homogeneous sub-groups (within-group homogeneity) that differ as much as possible from one another (between-groups heterogeneity) (Clatworthy et al., 2005). These analyses can highlight underlying structures, reveal natural classifications, or compress a large amount of data for synthesis purposes (Jain, 2010). They also offer the advantage of satisfactory statistical power and frequent use with relatively small participant samples (Dalmaijer et al., 2022; Molenaar et al., 2022).

In the field of language disorders, cluster analyses have been used to question, clarify, or confirm diagnoses of aphasia or primary progressive aphasia (e.g., Akinina et al., 2021; Crary et al., 1992; Hoffman et al., 2017; Leyton et al., 2014; Wicklund et al., 2014). They have also been used to highlight different language performance profiles in populations known for their symptom heterogeneity, such as people with aphasia, traumatic brain injuries, or right-hemisphere damage (e.g., Akinina et al., 2021; Champagne-Lavau & Joannette, 2009; Cordonier et al., 2020, 2023). In these studies, cluster analyses have made it possible to identify main language patterns and explore their underlying mechanisms by comparing the clusters on different measures (e.g., socio-demographic, clinical, or neuropsychological measures). This is the approach taken in the present article.

Aims of the study and hypotheses

Our study aimed to use cluster analysis on tense production performance to identify patterns of dissociation between tenses in PWA and explore the factors likely to underlie these patterns. More precisely, our first objective was to determine the main patterns of dissociation between the past, present, and future tenses in PWA. Given the large inter-individual variability demonstrated in the literature (e.g., El Ouardi, 2021; Faroqi-Shah & Friedman, 2015; Fyndanis, Arcara, Capasso, et al., 2018), the main patterns of tense dissociation in PWA are challenging to foresee. The performance pattern predicted by the PADILIH (i.e., past < non-past) should, however, emerge in one of the clusters. Secondly, we aimed to investigate which clinical factors (type of aphasia, severity of language disorders) and cognitive factors (executive functions and temporality) were likely to differentiate the PWA subgroups obtained. The type of aphasia should not differentiate the patterns, given the similarity of the profiles observed in people with fluent and non-fluent aphasia (Cordonier et al., 2024). On the other hand, the severity of language impairment could influence performance (Akinina et al., 2021; Bos & Bastiaanse, 2014), leading to

a pattern of impairment of all tenses, without dissociation, in PWA with the most severe language disorders. Regarding cognitive factors, a performance pattern with selective past tense impairment may be associated with poor working memory, given the discourse linking required in this condition (Bastiaanse et al., 2011). Hypotheses about other executive functions and temporality will be exploratory, given the lack of literature about them.

Materials and method

Participants

Participants with aphasia ($N = 21$; 10 with fluent aphasia and 11 with non-fluent aphasia) were similar to those described in Part I of our article (Cordonier & Fossard, *in press*; see [Appendix A](#) for the individual characteristics). They were recruited from different hospitals in the French-speaking part of Switzerland and met the following inclusion criteria: (i) to have chronic fluent or non-fluent aphasia secondary to a left unilateral stroke; (ii) the primary manifestation of aphasia was difficulty in sentence production; this criterion was verified using the clinical judgment of the speech-language pathologist treating the participant, and by the administration at the start of the study of two tasks: a picture description task, for which grammatical errors were expected, and a verbal flexion task from a syntactic production battery (BEPS; Coulombe et al., 2019), for which a score below the 5th percentile was expected; (iii) to have French as their first language. Exclusion criteria included the presence of (i) moderate or severe oral and written comprehension disorders that could affect comprehension of instructions and tasks (assessed by the speech-language pathologist treating the participant using clinical judgment and word-picture and sentence-picture matching tasks in oral and written modalities); (ii) a moderate or severe speech disorder; (iii) a history of a psychiatric disorder according to DSM-V criteria (American Psychiatric Association, 2013); (iv) symptoms of an alcohol or drug dependence disorder according to DSM-V criteria; (v) significant uncorrected vision and/or hearing impairment.

The diagnosis and type of aphasia (fluent versus non-fluent) were determined from the latest speech-language pathology reports using various language tests and clinical judgment. At the start of the study, PWA also completed a picture description task (Brookshire & Nicholas, 1993). An independent judge listened to each picture description and classified participants as having either fluent or non-fluent aphasia. A measure of fluency, speech productivity, was also calculated by dividing the pure speaking time (time without silences) by the total speaking time. This measure is known to be highly sensitive for distinguishing between fluent and non-fluent speech (Park et al., 2011). Using descriptive statistics from Park et al. (2011), speech was characterized as fluent (speech productivity > 53%) or non-fluent (speech productivity < 53%). The final classification of aphasia type (fluent versus non-fluent) was based on the greatest agreement between the speech-language pathology reports and the two analyses of the picture description. Eleven participants were thus classified as non-fluent (diagnosed with Broca's aphasia or

Table 1. Examples of the past, present and future conditions of the verb inflection production task.

Past	Present	Future
Manger	Réunir	Sortir
<i>Eat</i>	<i>Gather</i>	<i>Leave</i>
Il y a 5 ans, vous _____	Maintenant, tu _____	Dans plusieurs années, tu _____
<i>Five years ago, you _____</i>	<i>Now, you _____</i>	<i>In several years, you _____</i>
(Target: mangiez/ate)	(Target: réunis/gather)	(Target: sortiras/will leave)

transcortical motor aphasia), and ten participants were classified as having fluent aphasia (diagnosed with Wernicke's, conduction, anomia, or transcortical sensory aphasia).

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 before enrolment.

Material and procedure

Time reference

In Part I of our paper (Cordonier & Fossard, [in press](#)), three tasks were used: verb inflection production (T1), verb inflection selection (T2), and temporal adverb selection (T3). In Part II, analyses were carried out only on the first verb inflection production task, as this was the only task to show a tense effect (past < non-past) in Part I of our paper. Moreover, this task resembles the tense production tasks used in the literature, as forced-choice selection tasks are sometimes considered as comprehension tasks (Kok et al., 2007).

The verb inflection production task consisted of inflecting a verb given in the infinitive (e.g., *manger* – *to eat*) in a sentence beginning with a temporal adverb inducing past (*il y a cinq ans* – *five years ago*), present (*maintenant* – *now*) or future (*dans plusieurs années* – *several years from now*) (see [Table 1](#)). The verb and supporting sentence (e.g., *eat; now you _____*) were presented in writing in a PowerPoint and read aloud by the examiner. The participant was then asked to inflect the verb in the correct tense. Verbs were controlled for frequency (Lexique database; New et al., 2004), length of the infinitive form (1–4 syllables), and lexical aspect (activities only). The agreement (2nd person singular *tu* or plural *vous*) was manipulated to avoid automatism or perseveration. Regularity was also manipulated in the task. In French, verbs can be regular (e.g., *manger-mangeait* – *eat-ate*), pseudo-regular (e.g., *réagir-réagissait* – *react-reacted*), irregular without stem change (e.g., *convaincre-convainquait* – *convince-convincing*), and irregular with stem 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). Each form of regularity was thus present in equivalent numbers in each tense.

Language and cognitive tests

Several French language tests were administered to the participants beforehand to assess the severity of their language disorders. The *Grémots – Batterie d'évaluation des troubles du langage dans les pathologies neurodégénératives* (Grémots – Assessment battery for language disorders in neurodegenerative diseases; Bézy et al., 2016) was used to evaluate naming, repetition, verb fluency and reading

aloud. Participants were asked to name color photographs depicting objects (nouns) or actions (verbs). The number of correct answers out of 36 was recorded as the naming score. Participants were also instructed to name as many verbs as possible within two minutes. The total number of unique verbs provided was recorded as the verb fluency score. The third task involved repeating ten words of varying length and phonological complexity. The number of correct repetitions was recorded as the word repetition score. Finally, participants were asked to read 30 words (15 regular, 15 irregular) that varied in frequency and complexity. The number of correctly read words was used as the word reading aloud score. Comprehension was assessed using the *TICSf-12 - Test Informatisé de Compréhension Syntaxique en français* (TICSf-12 - Computerized French Syntax Comprehension Test; Python et al., 2013). This test required participants to match words and sentences presented orally to one of five multiple-choice pictures (including the target picture, three semantic or syntactic distractors, and an "other" option if none of the pictures matched). The correct response scores were recorded out of 6 for words and 12 for sentences, providing a measure of oral comprehension for words and sentences.

Executive functions were assessed with standardized neuropsychological tests. Verbal and non-verbal working memory were evaluated using backward span tasks. In the verbal condition, participants were asked to recall a sequence of digits in reverse order, with the length of the sequence increasing progressively (WAIS-IV; Wechsler, 2008). In the non-verbal condition, participants had to reproduce, in reverse order, the sequence of blocks touched by the examiner (MEM-III; Wechsler, 2001). The maximum spans, representing the longest sequence of digits or blocks correctly recalled, were recorded as measures of working memory. Mental flexibility was assessed using the Color Trails Test (CTT; D'Elia et al., 1996). In the first part (CT1), participants connected in ascending order numbers from 1 to 25, which were presented in pink and yellow circles. In the second part (CT2), numbers from 1 to 25 were again presented but in duplicate (pink and yellow), and participants had to connect the numbers in ascending order while alternating between the colors. An interference index was calculated as follows: $(CT2 \text{ time} - CT1 \text{ time}) / CT1 \text{ time}$. A higher index indicated lower mental flexibility. Inhibition was measured using the Go/No-Go test (FAB; Dubois et al., 2000). Participants were instructed to tap the table once when the examiner tapped once (Go) and to refrain from tapping when the examiner tapped twice (No-Go). The score was based on the number of correct responses out of 10. Finally, the conceptual-semantic notion of temporality was assessed with a new experimental task. Participants were presented with a temporal arrow indicating past (left), present (middle), and future (right). Forty temporal adverbs referring to either the past (e.g., last week, recently) or the future (e.g., in 5 years, next weekend) were presented both in written and spoken forms. Participants were required to point to the corresponding side of the arrow (left for past, right for future). The score was the number of correct responses.

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.

Data analysis

Responses to the verb inflection production task were recorded, transcribed, and scored 0–1 according to response accuracy. All tenses corresponding to the temporal frame, regardless of their aspectual value, were accepted, as were self-corrections within 10 seconds. Errors irrelevant to the present study (e.g., paraphasias on the stem – *mageais for *mangeais*) were not penalized. Errors were then classified into five categories: (i) substitution of one tense for another (e.g., production of the present tense instead of the future 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 *convindrez*); (v) others (e.g., non-responses, verb changes).

The cluster analyses were then performed using R (R Development Core Team, 2008), with the squared Euclidean distance as a similarity measure. Two main clustering methods were used (Clatworthy et al., 2005). The first method, hierarchical agglomerative cluster analyses using Ward's method (Ward, 1963), starts with individual cases and, step by step, groups them into clusters according to their similarity. The second method, iterative partitioning methods (k-means; Jain, 2010), involves determining an iterative number of clusters (k) and then calculating cluster centroids for each of these k -clusters. Participants are then allocated to the clusters with the closest centroid. The k-means method was performed with 1,000 sets of initial values for a number of clusters from 2 to 6.

Cluster analyses were conducted on the differences in performance between tenses for PWA in the verb inflection production task. Specifically, the analyses used scores derived from subtracting the past tense from the present tense, the past tense from the future tense, and the future tense from the present tense. This dependent variable was chosen in order to group participants not according to their success score in each condition but according to the gaps between the different tenses. Thus, participants with significant gaps between past and present tenses, for example, irrespective of their raw score in each of these conditions, should be grouped together.

We then used the elbow and silhouette methods to determine the optimal number of clusters. The elbow method (Kodinariya & Makwana, 2013) visually assesses the variance explained by an increasing number of clusters. It allowed us to identify the point at which the marginal gain in variance explained diminishes, forming an "elbow" in the graph, indicative of the optimal number of clusters. The silhouette method (Rousseeuw, 1987) is another visual method that examines the disparity between the average distances within clusters and those to neighboring clusters for each data point. A negative value suggests the misclassification of a participant. These internal validation techniques aimed to confirm the coherence and distinctiveness of the identified clusters, thus strengthening our confidence in the validity of the clustering results.

To meet our first objective (main patterns of tense dissociation among PWA), we then conducted generalized linear mixed models. These models are particularly well suited to handling small sample sizes, as may be the case following cluster analyses, due to their flexibility and robustness (Bolker et al., 2009). They were carried out on the PWA performance on the verb inflection production task. Tense (past, present,

future) and its interaction with the clusters were included as fixed effects. Random effects for items and participants and random slopes for tense were included where relevant. Likelihood ratio tests were systematically conducted to compare models with the main effects or interactions against those who were without to determine the significance of these factors (Pinheiro & Bates, 2000). Post-hoc tests were performed with Tukey correction for multiple comparisons using “lsmeans” package (Lenth, 2016). These analyses were conducted using R (R Development Core Team, 2008) and the lme4 package (Bates et al., 2015), with a significance level set at $p < 0.05$.

Our second objective (explanatory factors for the different dissociations between tenses) was achieved by comparing the group averages for socio-demographic data and language and cognitive scores between cluster-defined groups. The choice of statistics (i.e., Mann-Whitney) and significance level (i.e., $p < .05$) was determined by the number of clusters obtained (i.e., two, see below). These statistical analyses were conducted using SPSS, version 28.0.0.

Results

Cluster analyses

The individual scores and cluster membership are given in [Appendix B](#). The dendrogram using Ward’s method on the differences in performance between the tenses of the PWA on the verb inflection production task is shown in [Figure 1\(a\)](#). The results of the elbow and the silhouette statistic methods, performed on the different clusters obtained using the Ward’s and the k-means methods, are shown in [Figure 1\(b-e\)](#). Overall, the Ward’s and k-mean methods converged and suggested that the optimal number of clusters was three. Insofar as a cluster contained only one participant (P4), inferential statistical analyses were performed on the two remaining clusters, the PWA_1 ($N = 14$) and PWA_2 ($N = 6$) subgroups. Only descriptive data from participant P4 will be presented.

Tense effect and interaction tense \times clusters

The percentages of correct responses at each tense (past, present, and future) for the two PWA clusters in the verb inflection production task are shown in [Figure 2](#). The likelihood ratio tests revealed no significant effect of clusters ($\chi^2(1) = 0.479, p = .489$) but a significant effect of tense ($\chi^2(2) = 11.943, p = .003$). Posthoc analyses showed worse performances in the past tense than in the present ($\beta = -3.373, SE = 0.484, z = -1.63, p = .002$) and future tenses ($\beta = -1.35, SE = 0.526, z = -2.572, p = .027$). There was no significant difference between the present and future tenses ($\beta = 0.28, SE = 0.548, z = 0.510, p = 0.866$).

The interaction between clusters (PWA_1, PWA_2) and tense (past, present, future) was significant ($\chi^2(2) = 47.991, p < .0001$). The interaction broken down by cluster showed that in the PWA_1 cluster, performance was worse in the past ($\beta = 1.745, SE = 0.489, z = 3.566, p = .0491$) and future ($\beta = 1.137, SE = 0.484, z = 2.351, p = .0273$) than in the present. There was no significant difference between past and future ($\beta = 0.608, SE = 0.484, z = 1.257, p = 0.4199$). The PWA_2 subgroup had worse performances in the past ($\beta = 2.844, SE = 0.575, z = 4.944, p < .0001$) and present ($\beta = 1.682,$

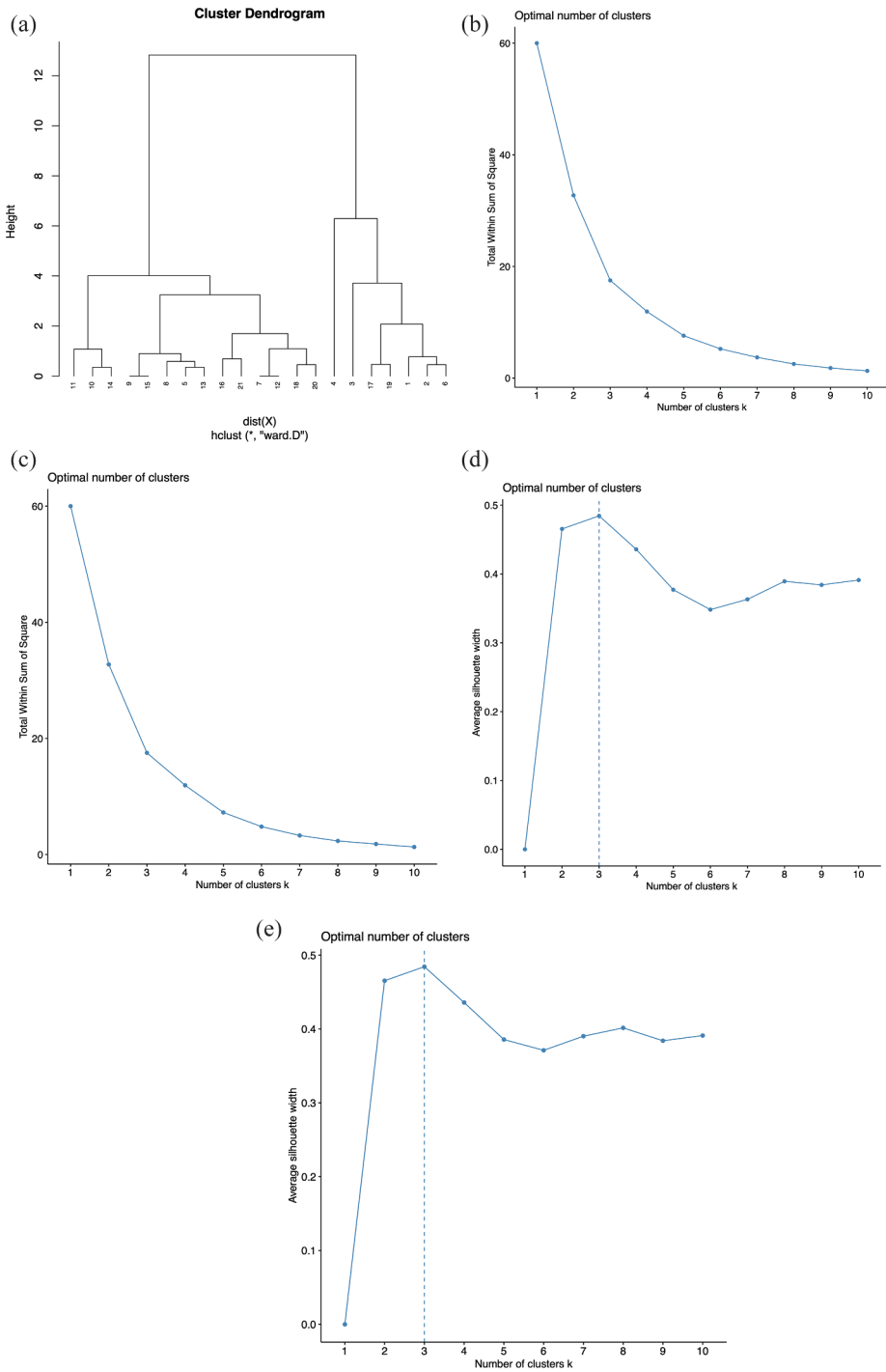


Figure 1. Dendrogram using the Ward’s method (a) and optimal number of clusters according to the elbow method [(b) for the Ward’s method and (c) for the k-means method] and the silhouette method [(d) for the Ward’s method and (e) for the k-means method]. Note. The elbow method is a heuristic method involving plotting the sum of squares within clusters and selecting the curve’s elbow point as the optimal number of clusters. In Figure 1(b,c), a subtle curvature appears when the cluster number is set to 3. Additionally, the ideal number of groups may be determined by maximizing the overall average silhouette, as illustrated in Figure 2(d,e) with the dotted line ($N = 3$).

SE = 0.556, $z = 3.025$, $p = .0070$) than in the future. There was no significant difference between past and present ($\beta = -1.163$, SE = 0.563, $z = -2.066$, $p = .0970$). The interaction broken down by tense revealed that the PWA_1 cluster had a worse performance than the PWA_2 cluster in the future ($\beta = -1.75$, SE = 0.642, $z = -2.723$, $p = .0065$). The difference between the PWA_1 and PWA_2 clusters was not significant in the past ($\beta = 0.49$, SE = 0.648, $z = 0.756$, $p = .4496$) and present ($\beta = 1.07$, SE = 0.636, $z = 1.685$, $p = .0920$).

Regarding participant P4 (isolated cluster), the descriptive data showed poorer performance in the past than in the present and future, and comparable performance between the present and future (see [Appendix C](#)).

Error analysis

The errors made by the two clusters for each tense are detailed in [Table 2](#). In cluster PWA_1 (past and future < present), the majority of errors consisted of substitutions of one tense for another (e.g., production of the present form *remplis* – *fill* instead of the past form *remplissais* – *filled*). These participants also produced other responses (e.g., no answer), unmarked forms (i.e., infinitive), and paraphasias (e.g., production of **tradois* – **translute* instead of *traduis* – *translate*). Participants in cluster PWA_2 (past and present < future) produced a large majority of substitutions, mainly by future (e.g., production of the future form *confondrez* – *will confuse* instead of the past form *confondiez* – *confused*). These errors were followed by a few paraphasia (e.g., production of **débattas* – **debatad* instead of *débattais* – *debated*), other responses (e.g., no answer), unmarked forms (i.e., infinitive), and regularizations (e.g., production, for the irregular verb *retenir* – *retain*, of **reteniras* instead of *retiendras* – *will retain*).

Clinical and cognitive factors

Means, standard deviations, and p-values for socio-demographic variables, language, and neuropsychological tests for the two clusters are detailed in [Table 3](#). Mann-Whitney tests revealed significant differences for the time post-onset, with a longer time post-onset in the PWA_2 cluster than in the PWA_1 cluster. No other measures (socio-demographic, language, and neuropsychological) differentiated between the two clusters. In addition, both clusters included participants with fluent and non-fluent aphasia (PWA_1: 7 with fluent aphasia and 7 with non-fluent aphasia; PWA_2: 2 with fluent aphasia and 4 with non-fluent aphasia).

Discussion

The present study aimed (1) to identify the main patterns of dissociation between tenses in PWA and (2) to explore the factors likely to underlie these patterns. To this end, we performed cluster analyses on the differences in scores obtained by 21 French-speaking PWA in the different conditions (i.e., past, present, future) of a verb inflection production task. We then compared the clusters on clinical and neuropsychological measures to identify the factors that differentiated them.

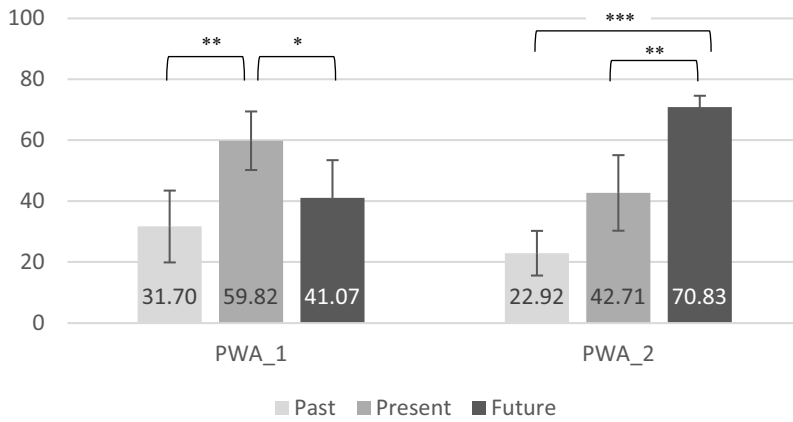


Figure 2. Percentage of correct responses obtained by the two clusters (PWA_1 and PWA_2) for the three tenses (past, present, future) of the verb inflection production task.

Table 2. Error types (percentages) in each condition (past, present, future) in the verb inflection production task for the two clusters (PWA_1 and PWA_2).

Target form → Produced form ↓	Past		Present		Future		Total	
	PWA_1	PWA_2	PWA_1	PWA_2	PWA_1	PWA_2	PWA_1	PWA_2
Substitutions								
Past	–	–	1.34%	1.91%	4.29%	0.64%	5.63%	2.55%
Present	6.70%	4.46%	–	–	4.83%	1.91%	11.53%	6.37%
Future	10.72%	22.93%	6.17%	20.38%	–	–	16.89%	43.31%
Other	6.17%	10.19%	1.07%	3.82%	2.68%	2.55%	9.92%	16.56%
Unclassifiable	0.54%	0%	0%	0%	0%	0%	0.54%	0%
Total	24.13%	37.58%	8.58%	26.11%	11.80%	5.10%	44.51%	68.79%
Unmarked	5.90%	0.64%	5.63%	4.46%	5.09%	1.27%	16.62%	6.37%
Paraphasia	5.36%	4.46%	2.68%	2.55%	7.77%	3.82%	15.81%	10.83%
Regularization	0.27%	0%	1.88%	0%	3.22%	5.10%	5.37%	5.10%
Other	5.09%	4.46%	5.36%	1.90%	7.24%	2.55%	17.69%	8.91%

Regarding our first aim, the cluster analysis revealed two main clusters: one (PWA_1; $N = 14$) with worse performances in the past and future than in the present, and the other (PWA_2; $N = 6$) with worse performances in the past and present than in the future. This result thus confirms the heterogeneity of verb inflection performance in PWA (e.g., El Ouardi, 2021; Faroqi-Shah & Friedman, 2015; Fyndanis et al., 2023). It is also consistent with the number of subgroups classically observed following cluster analyses in PWA (i.e., between 2 and 4 clusters; Akinina et al., 2021; Hoffman et al., 2017; Wicklund et al., 2014).

In terms of performance patterns, it is interesting to note that both clusters behaved similarly in the past tense. Indeed, no significant difference was found between the two clusters in the past tense. Moreover, the past tense was the most impaired of the tenses in both clusters and in Participant P4. These results thus corroborate those of Martínez-Ferreiro and Bastiaanse (2013), whose study of participants speaking Spanish, a Romance language close to French, also found poor performance in the past tense. More generally, they support the PADILIH (Bastiaanse

Table 3. Socio-demographic, language and neuropsychological data for the two clusters (PWA_1 and PWA_2).

	PAA_1		PAA_2		U	p-value
	Mean	SD	Mean	SD		
<i>Socio-demographic</i>						
Age	62.64	14.32	66.83	8.52	48.0	.659
Education	12.64	3.39	13.67	3.01	51.5	.444
Post-onset (months)	35.50	71.85	81.17	54.60	68.0	.033
<i>Language</i>						
<i>Oral expression</i>						
Picture Naming – Nouns (/36)	25.29	4.94	25.33	3.88	40.0	.904
Picture Naming – Verbs (/36)	20.43	5.76	18.33	8.82	38.5	.779
Verb fluency	15.43	7.42	11.50	5.01	28.5	.274
Word repetition (/10)	4.36	3.73	7.17	1.84	61.0	.130
Word reading aloud (/30)	23.50	4.09	24.50	2.88	48.0	.659
<i>Oral comprehension</i>						
Words (/6)	5.71	0.47	6	0	54.0	.353
Sentences (/12)	9.36	1.74	9	2.61	40.0	.904
<i>Executive functions</i>						
Verbal working memory (span backward)	2.43	0.65	2.83	0.75	55.5	.274
Spatial working memory (span backward)	4.64	1.15	4.83	0.75	48.0	.659
Mental flexibility (index CTT)	1.03	0.47	1.41	0.55	60.0	.153
Inhibition – Go-Nogo (/10)	9.07	1.77	9.83	0.41	51.0	.494
<i>Temporality</i>						
Time arrow (/40)	35.86	4.35	37.83	2.40	55.5	.274

et al., 2011), which postulates greater difficulty for the past tense in PWA because of the discourse linking that must be established between the speech time and the event time, which is prior. On the other hand, performance in the present and future tenses seemed to distinguish the two clusters, with the future tense being particularly discriminating, as evidenced by significant inter-cluster differences only in this tense. These different patterns are discussed in more detail below, in light of the hypotheses reported in the literature.

Most participants (cluster PWA_1; $N = 14$) showed poorer performances in the past and future than in the present. These findings challenge the position of the future in the PADILIH. Indeed, based on Zagona (2003, 2013), the PADILIH suggests that the future is a subclass of the present insofar as it is derived from the present through modal and aspectual features. Moreover, since the event has not yet occurred and may never occur, discourse linking in the future tense is not necessary. Therefore, the future should be preserved in PWA in the same way as the present. While several studies have confirmed this equivalent preservation of the present and future tenses (Bastiaanse et al., 2011; Stavrakaki & Kouvava, 2003; Yarbey Duman & Bastiaanse, 2009), some studies have also found a worse performance in the future than in the present, as in our PWA_1 cluster (Koukouloti & Bastiaanse, 2020; Martínez-Ferreiro & Bastiaanse, 2013; Nanousi et al., 2006; Tsiwah et al., 2021; Varlokosta et al., 2006). Several explanatory hypotheses have been put forward to account for this impairment of the future.

Semantic/pragmatic factors could explain poorer performance in the future than in the present (Koukouloti & Bastiaanse, 2020). Indeed, Martinez-Ferreiro and Bastiaanse (2013) have suggested that the future tense is distinct from the present because the event time is not simultaneous with the speech time. Consequently, the future might imply a discourse linking, like the past (Avrutin, 2000, 2006). The cognitive cost induced by this discourse linking could thus lead to worse performances in the past and future than in the present, as observed in the cluster PWA_1. Furthermore, the future tense could also be problematic for some PWA due to its “irrealis” dimension, the future events being not immutable and having no real existence (Koukouloti & Bastiaanse, 2020; Pinker, 2007; Rofes et al., 2014).

While these semantic/pragmatic factors (i.e., discourse linking and the “irrealis” dimension of future) likely explain the performance pattern of cluster PWA_1 (past and future < present), the question arises differently for cluster PWA_2 ($N=6$), which had worse performances in the past and present than in the future. A possible explanation for this pattern lies at the morphological level (Koukouloti & Bastiaanse, 2020; Martínez-Ferreiro & Bastiaanse, 2013). Indeed, unlike other languages (e.g., English or German), French has morphologically simple (i.e., monolectic) forms for both present and future tenses. However, the process of deriving from infinitives differs between these two tenses.

To form the present tense, the process is variable, even within the same conjugation person, and generally involves removing the infinitive ending (e.g., for the 2nd person singular: *finir* - finish → *tu finis* - you finish; *manger* - eat → *tu manges* - you eat). In contrast, forming the future tense is more regular and involves the systematic addition of the same ending to the infinitive for each conjugation person (e.g., the addition of the ending *-ras* for the 2nd person singular: *finir* - finish → *tu finiras* - you will finish; *manger* - eat → *tu mangeras* - you will eat). Thus, producing the future tense in the verb inflection task may be easy – and sometimes even more effortless than producing the present tense – because the PWA could simply repeat or read the infinitive provided by the examiner and add the expected future ending.

Faroqi-Shah and Friedman (2015) suggested that the variability observed in PWA could be explained by the fact that some participants with aphasia would favor an inflectional strategy and use it frequently or even overuse it. Producing the future tense might be a low-cost strategy for certain participants with preserved morphological skills (i.e., affixation). To test whether our participants in the PWA_2 cluster had such preserved skills, we conducted verb regularity analyses (see Appendix D for detailed results). These analyses showed better performance for regular verbs compared to irregular verbs. This finding supports our hypothesis that certain participants with aphasia who have preserved concatenative morphological abilities – the PWA_2 cluster in our study – may favor the production of verb forms resulting from the application of an affixation rule (Pinker, 1998; Ullman et al., 1997, 2005), such as the future and its systematic addition of the same ending to the infinitive for each conjugation person (e.g., the ending *-ras* for the 2nd person singular). This strategy of future overproduction would lead to better performance in the future than in the past and present tenses. This hypothesis is supported by the error analysis, which showed a large majority of past and present substitutions by future (about 43% of the errors) in this cluster (see Table 2).

Finally, cognitive factors could also explain the different performance pattern (Fyndanis, Arcara, Capasso, et al., 2018). This origin was explored in our second

aim, which focused on the clinical and cognitive factors differentiating the clusters. At the clinical level, it is interesting to note that the type of aphasia does not seem to have an impact on the patterns of dissociation between tenses. Indeed, participants with fluent and non-fluent aphasia belonged to both clusters. These results thus confirm the findings of a recent meta-analysis (Cordonier et al., 2024), which showed comparable performance profiles between people with fluent and non-fluent aphasia. Similarly, the two clusters did not differ in language measures. This finding suggests that the different patterns of dissociation between the tenses are not associated with different levels of language impairment.

In contrast, the time post-onset was the only clinical measure that distinguished the two clusters, with a longer delay in the PWA_2 subgroup than in the PWA_1 subgroup. To our knowledge, the impact of stroke onset on time reference has never been studied. However, some longitudinal studies have shown that the strategies used by PWA in different language contexts evolve over time to gain in communicative efficiency (Penn, 1987; Wilkinson et al., 2007). Therefore, we could hypothesize that the more chronic participants in our study have had more time to develop strategies, such as the frequent use of the future tense. These strategies could enable them to improve their functional communication and reduce the cognitive cost induced by verb inflection.

Regarding the cognitive profiles, no significant differences were observed between the two groups for the executive and temporality measures. In line with the hypothesis of frequent use of the future strategy in the PWA_2 cluster, we could have hypothesized that this subgroup had greater difficulties with inhibition and flexibility, not allowing them to switch strategies. The lack of differences between the clusters on these two executive measures does not rule out this hypothesis. Indeed, it is likely that both PWA clusters had executive disorders (Olsson et al., 2019; Purdy, 2002). However, these difficulties may have manifested differently in the two clusters (e.g., difficulties in switching strategy in PWA_2 versus difficulties in inhibiting a previously produced tense in PWA_1). On the other hand, it is also possible that these executive functions play only a minor role in tense production. Part I of our paper (Cordonier & Fossard, *in press*) demonstrated no significant effect of mental flexibility and inhibition on the performance of participants with fluent and non-fluent aphasia in different time reference tasks, thus corroborating this hypothesis. Further studies using finer executive measures are needed to shed light on this issue.

Implications

The main objective of Part II of this paper was to explore the heterogeneity of PWA in tense production. Taking this variability into account in our study has several research and clinical implications. Firstly, it allows us to nuance and reconcile the data in the literature, which are generally derived from group analyses. Indeed, it is interesting to note that when tense was analyzed across all our participants with aphasia (i.e., simple tense effect), a pattern of performance similar to that predicted by the PADILIH (i.e., past < present and future) emerged. However, when we accounted for heterogeneity in performance using cluster analyses, we found that the majority of the participants (PWA_1 cluster – 14 participants) showed similar difficulties with past and future tenses. Conversely, the six participants in cluster PWA_2 produced a large number of verbs in the future tense and thus performed better in the future than in the other tenses. We can, therefore, conclude

that the group result (i.e., past < present and future) was carried by the subgroup of 6 participants with aphasia (cluster PWA_2), who increased the group mean for the future condition.

These results also suggest that the future may be subject to greater inter-individual variability than other tenses. Several hypotheses related to the “irrealis” dimension or the morphological complexity of this tense have been put forward above to explain the particular case of the future. In future studies, it would be interesting to combine behavioral data with neuroimaging data to gain new insights into what differentiates people who perform better or worse in the future tense. Indeed, several neuroimaging studies have shown a common neural network during projections into the past or future (Buckner & Carroll, 2007; Schacter & Addis, 2007). However, specific brain regions might be involved in each of these tenses. The future would thus rely more than the past on the inferior frontal and lateral temporal gyri – regions involved in semantic memory (Viard et al., 2011). These results must be treated with caution, as they relate to discursive tasks involving recalling or envisioning past and future events. However, they are interesting because they shed new light on the production of the future tense and suggest a more amnesic origin of the difficulties, which has never been explored in PWA.

Our findings on future tense performance also raise important cross-linguistic considerations. One anonymous reviewer noted that certain factors underlying future tense production, such as semantic/pragmatic factors related to discourse linking or the irrealis dimension of the future tense, are likely to operate similarly across different languages. This suggests that difficulties with the future tense should be observed in studies involving various languages. This assumption is confirmed by studies showing poor future tense performance in speakers of Greek (Koukouloti & Bastiaanse, 2020; Varlokosta et al., 2006), Akan (Tsiwah et al., 2021), and Spanish and Catalan (Martínez-Ferreiro & Bastiaanse, 2013). On the other hand, other factors like morphological complexity would vary across languages: better performance for the future tense is more likely in languages with a monolectic form of the future tense compared to those with a periphrastic form. This hypothesis is supported by a recent cross-linguistic study (Fyndanis et al., 2023), which analyzed past and future tense performance in English, Russian, Greek, and Italian speakers with aphasia. Several double dissociations between past and future were observed in their participant. Notably, the pattern of better performance in the future than in the past was observed only in some Italian-speaking speakers, Italian being the only one of the four languages to use mainly a monolectic form in the future tense (like French).

Finally, analyses at the individual level are also of great clinical importance. It is well known that PWA have heterogeneous symptoms, reflecting different underlying deficits. The cognitive neuropsychological approach emphasizes the importance of identifying the deficit underlying the language impairment of each individual with aphasia. This underlying deficit should then be defined as the treatment target to reduce the symptoms and encourage the generalization of acquired skills (Coppens & Patterson, 2017; Whitworth et al., 2014). This approach has been used to treat various language disorders, such as anomia, oral comprehension, reading, or writing (Whitworth et al., 2014). However, its application to

the field of time reference is only recently emerging due to the poor understanding of the mechanisms underlying it.

In Part I of our article (Cordonier & Fossard, [in press](#)), we reported that time reference difficulties may have multiple origins, particularly at a pre-phonological (i.e., encoding and retrieval of diacritic features) and/or morpho-phonological (i.e., affixation) level (Faroqi-Shah & Thompson, 2007; Pinker, 1998). These origins may differ from one patient to another and impact the type of therapy proposed to each patient. The few studies that have attempted to remediate verb inflection in PWA have targeted different underlying processes using phonological, semantic, or mixed therapies (see Ericson et al., 2023 for a review). However, the paradigm used in most studies consisted of administering therapies targeting different underlying processes to strengthen localization hypotheses on the assumption that “a treatment that directly addresses the underlying impairment is more likely to produce significant treatment and generalization gains when compared to a treatment that does not target the underlying source of verb inflection errors” (Faroqi-Shah, 2008, p. 3089). Given the limited number of studies on the remediation of verb inflection deficits, cluster analyses thus offer added value: they can highlight the most common patterns of disorder and encourage the development, as a first step in “modular therapies” compatible with the main profiles identified (Akinina et al., 2021). In a second step, these therapies could be further refined and personalized according to more individual analyses.

Limitations

Several limitations of the present study need to be addressed. Firstly, although the sample of participants with aphasia is comparable to or larger than that of other studies, it remains relatively small, even more so when cluster analyses were performed. As a result, one cluster included only 6 participants, making it difficult to generalize our results and reducing the statistical power of our analyses. Similarly, our study included participants with different types of fluent and non-fluent aphasia. However, our inclusion criteria and the type of task used excluded some participants with severe oral and/or written comprehension impairments, thus limiting the generalizability of our results to certain forms of aphasia (e.g., global aphasia). Secondly, we chose to use cluster analysis to present novel results that fall between the group and individual analyses used in most studies. In addition, these analyses are particularly interesting for highlighting the most common performance patterns. However, it is important to keep in mind that other patterns of dissociation between tenses are likely to exist at the individual level, albeit less frequently, as evidenced by the performance of participant P4 (see [Appendix C](#)). This participant showed the pattern predicted by PADILIH, with poorer performance in the past than in the present and future tenses. Interestingly, his cognitive profile seemed comparable to that of both groups, and he did not differ from the other participants in terms of clinical and socio-demographic variables. Further studies are needed to better understand the factors (e.g., neurological, strategies?) underlying these inter-individual differences.

Conclusion

Our study is the first to use cluster analyses to identify the main patterns of dissociations between tenses in PWA and the factors underlying these patterns. Our results revealed two main clusters that differed primarily in their future tense performance. They thus confirm the heterogeneity of verb inflection disorders in PWA. This heterogeneity might reflect different underlying deficits, which should be the focus of targeted therapies. Regarding the factors, the type and severity of aphasia and cognitive performance failed to account for the heterogeneity of tense patterns in PWA. On the other hand, a longer time post-onset, combined with frequent use of a future production strategy, may characterize a sub-group of PWA. Further studies exploring the heterogeneity of PWA in different tasks, in conjunction with various cognitive measures, will help us to gain insight into the different functional origins of these tense production difficulties.

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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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Appendices

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

Participant	Cluster	Past	Present	Future	Present – Past	Future – Past	Present – Future
P1	PAA_2	3	8	11	5	8	-3
P2	PAA_2	7	12	13	5	6	-1
P3	PAA_2	1	1	12	0	11	-11
P4	-	1	14	14	13	13	0
P5	PAA_1	2	8	6	6	4	2
P6	PAA_2	6	10	12	4	6	-2
P7	PAA_1	0	5	1	5	1	4
P8	PAA_1	1	7	3	6	2	4
P9	PAA_1	7	12	10	5	3	2
P10	PAA_1	9	12	12	3	3	0
P11	PAA_1	13	14	14	1	1	0
P12	PAA_1	8	13	9	5	1	4
P13	PAA_1	5	11	8	6	3	3
P14	PAA_1	7	10	9	3	2	1
P15	PAA_1	0	5	3	5	3	2
P16	PAA_1	5	10	3	5	-2	7
P17	PAA_2	2	5	10	3	8	-5
P18	PAA_1	5	8	5	3	0	3
P19	PAA_2	3	5	10	2	7	-5
P20	PAA_1	2	6	2	4	0	4
P21	PAA_1	7	13	7	6	0	6

The maximum score is 16 for the past, present and future conditions.

Appendix C. Results of the participant Ptemp

	Score participant P4
Verb inflection production task	
Past (/16)	1
Present (/16)	14
Future (/16)	14
Language	
<i>Oral expression</i>	
Picture Naming – Nouns (/36)	29
Picture Naming – Verbs (/36)	32
Verb fluency	27
Word repetition (/10)	3
Word reading aloud (/30)	24
<i>Oral comprehension</i>	
Words (/6)	6
Sentences (/12)	10
<i>Executive functions</i>	
Verbal working memory (span backward)	2
Spatial working memory (span backward)	4
Mental flexibility (index CTT)	1.85
Inhibition – Go/No-Go (/10)	9
Temporality	
Time arrow (/40)	37

Appendix D. Results of the regularity analyses

Generalized linear mixed models with regularity (regular, pseudo-regular, irregular with and without stem change) and its interaction with the clusters as fixed effects were carried out on the PWA performance on the verb inflection production task. Random effects for items and participants and random slopes for regularity were included where relevant. Post-hoc tests were performed with Tukey correction for multiple comparisons using the “lsmeans” package (Lenth, 2016).

The likelihood ratio tests revealed a significant effect of regularity for PWA ($\chi^2(3) = 18.261, p < .001$). Posthoc analyses showed better performance for the regular verbs than for the irregular verbs without stem change ($\beta = 1.886, SE = 0.481, z = 3.921, p = .0005$) and with stem change ($\beta = 1.787, SE = 0.478, z = 3.737, p = .0011$). There was no significant difference between the regulars and pseudo-regular verbs ($\beta = 0.721, SE = 0.471, z = 1.530, p = 0.42$), the pseudo-regular verbs and the irregular verbs without stem change ($\beta = 1.165, SE = 0.477, z = 2.444, p = 0.07$) or with stem change ($\beta = 1.065, SE = 0.474, z = 2.248, p = 0.11$), and the irregular verbs with or without stem change ($\beta = 0.010, SE = 0.479, z = 0.208, p = 0.99$). The interaction between group (PAA_1, PAA_2) and regularity (regular, pseudo-regular, irregular with or without stem change) was not significant ($\chi^2(3) = 4.060, p = 0.26$).