



Impact of digital tools for the development of written expression in German as a foreign language in young Spanish speaking adults

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Abstract

Written production in a foreign language presents a complex challenge that requires multiple skills, but it is an essential objective in our globally connected society. For Spanish speakers learning German, this task can be particularly challenging due to differences in linguistic structures, vocabulary, and orthography. This focus highlights the importance of understanding the strategies employed by writers, the challenges they encounter, and then the resources to improve writing skills. The present study aimed to characterise the process and product of writing in German as an Additional Language in Spanish speakers and investigate whether the use of digital resources enhance writing quality. To achieve the objective, young adults in higher education with Spanish as native language and learners of German as a foreign language participated in the study. Participants had to produce two written compositions in German, using Inputlog software, one of which they could use and consult digital tools to support them in the development of the task. Results showed that participants using digital tools produced longer, higher-quality texts with fewer errors compared to those without resources. Digital aids during text composition helped to reduce cognitive demands, improving both lexical accuracy and composition quality. The use of resources also led to more elaborated responses, enhancing text quality, whereas the absence of such tools resulted in more frequent pauses, errors, and shorter bursts of writing. These findings highlight the significant role digital tools play in supporting foreign language writing by reducing cognitive demands and enhancing text quality.

Keywords Written production · German as a foreign language · Digital tools · Educational technologies · Cognitive neuroscience

Extended author information available on the last page of the article

Introduction

Writing is indeed a keystone in both academic and professional domains, serving as the primary vehicle for transmitting and sharing ideas and knowledge (Bean, 2011; Swales & Feak, 2004). In academic life, competent students in writing are better equipped to organize their thoughts, articulate ideas clearly, and meet the demands of academic assessments (Fisher & Twist, 2011). In professional environments, clear and effective writing allows professionals to convey ideas, coordinate with teams, and report findings (Swales & Feak, 2004). Therefore, developing writing proficiency is critical, as it directly impacts one's ability to succeed and make meaningful contributions in both academic and professional contexts. In addition, writing in a foreign or second language (FL) plays a crucial role in today's globalized world, as more people are required to communicate effectively across linguistic and cultural boundaries (Marlina, 2013). This approach emphasizes the importance of understanding writing skills in a foreign language and the challenges that arise. It also highlights the need to identify and access resources that support the development of writing skills in a foreign language.

Extensive research has examined writing in both first and FLs (Bean, 2011; Swales & Feak, 2004). Most FL writing studies have focused on English (Chen, 2019; Dahlström, 2018; Lahuerta, 2017; Nation, 2001; Purcell et al., 2013; Wei et al., 2023; Woodworth & Barkaoui, 2020), with limited attention to languages like German, particularly in Spanish-speaking contexts. While digital tools are increasingly used to enhance writing proficiency (Dahlström, 2018; Purcell et al., 2013; Wei et al., 2023; Woodworth & Barkaoui, 2020), little research has explored their role in German FL writing for Spanish speakers. This gap highlights the need to understand the characteristics of German FL writing among Spanish speakers and how digital tools can support this process. Investigating these aspects could offer valuable insights into effective teaching strategies and the development of specialized digital resources. While studies have examined the benefits of grammar checkers, online dictionaries, editing tools, and keystroke logging in English writing (Dahlström, 2018; Han et al., 2021; Leijten & Van Waes, 2013; Levy & Stockwell, 2006; Pitukwong & Saraiwang, 2024), their impact on German writing proficiency for Spanish speakers remains underexplored. A deeper analysis of linguistic challenges in German FL writing and the support provided by digital tools could inform pedagogical strategies and promote the effective use of technology, ultimately fostering greater confidence and proficiency in academic and professional writing.

Cognitive process in writing and key aspects of high-quality texts

Before addressing the obstacles of writing in a FL, it is essential to understand the cognitive processes involved and define what constitutes a high-quality text. Several models have been proposed to explain text production (Bereiter & Scardamalia, 1987; Chenoweth & Hayes, 2001; Hayes, 2012a, b; Kellogg, 1999). Among them, the cognitive process model of writing by Chenoweth and Hayes (2001) provides a comprehensive framework for understanding the complexity of text composition. This

model identifies four key cognitive components: proposer, translator, transcriber, and evaluator. Each stage plays a distinct role in the composition process, engaging both linguistic and non-linguistic resources, making writing a cognitively demanding task (Berninger & Amtmann, 2003; Chenoweth & Hayes, 2001; Connelly et al., 2012). The proposer generates the writer's goals and ideas, involving the conceptualization and organization of thoughts before they are translated into words. The translator converts these abstract ideas into a linguistic message, requiring the selection of appropriate vocabulary and the construction of grammatically correct sentences. This phase is crucial, as it determines how effectively the writer conveys their intended meaning. The transcriber then produces the text in its physical form, either through handwriting or typing. Finally, the evaluator reviews and assesses the text, ensuring it meets the writer's communicative goals. This model highlights that writing is not a linear process but rather an interaction of components, each relying on cognitive resources. When one component is overloaded—such as struggling with spelling or sentence construction—it may limit the cognitive capacity available for other aspects of writing, ultimately affecting the overall quality of the text.

Expanding on this model, Hayes (2012a, b) proposed that the writing process consists of three hierarchical levels: control, processing, and resources. The control level initiates writing through motivation and goal-setting, with motivation being a key factor that can either facilitate or hinder the writing process (Hayes et al., 1990; Hayes, 2012b; Troia et al., 2012). The processing level involves the interaction between the task environment and writing processes, including responding to stimuli, translating ideas into text, and revising. Hayes (2012b) redefined planning and reviewing as specific writing activities rather than core processes (Hayes & Berninger, 2014). A key aspect of this level is transcription, initially overlooked but later recognized as a limiting factor, particularly for novice writers who are still developing the automation of this skill (Berninger et al., 1994; Hayes & Chenoweth, 2006). Finally, the resources level encompasses the available cognitive abilities, such as attention, reading skills, working memory, and long-term memory, all of which influence writing execution (Hayes & Chenoweth, 2006). This integrated framework underscores the interplay between motivation, cognitive capacity, and writing processes, highlighting the impact of transcription and cognitive constraints on writing performance, particularly among novice writers. By combining the cognitive process model of writing and the three-level hierarchy proposed by Hayes (2012a, b), this approach offers a comprehensive understanding of the cognitive demands of writing and its implications for instruction and skill development.

Regarding high-quality writing, it is characterized by several key features: clarity (the intended message is easily understood), coherence (ideas are logically connected), structure (the organization facilitates comprehension), effective use of vocabulary and syntax, and accuracy (minimal errors) (Nunan & Choi, 2022). Writing requires not only mastery of the subject matter and the ability to organize ideas effectively but also proficiency in vocabulary, syntax, and orthographic representations. A rich vocabulary enables writers to express themselves more precisely, enhancing the overall impact of their communication. Conversely, limited vocabulary often results in simplistic, repetitive language that may reduce the effectiveness of the text. Furthermore, spelling ability directly affects transcription processes and

indirectly influences translation processes. Efficient spelling reduces cognitive strain, allocating more mental resources to higher-level writing processes such as structure and argument development (Graham & Santangelo, 2014). Research on dyslexia and writing difficulties highlights that limited vocabulary and spelling difficulties can significantly impact writing quality (Afonso et al., 2022; Connelly et al., 2006; Sumner et al., 2014). These difficulties not only affect spelling accuracy but also place additional cognitive demands on writers, who must allocate more attention to mechanics (e.g., spelling, grammar, word choice) rather than higher-order composition skills such as coherence and organization.

In summary, writing high-quality texts requires mastery of various language skills and the efficient coordination of different writing processes, all of which directly impact the final output (Berninger & Amtmann, 2003; Chenoweth & Hayes, 2001; Hayes, 2012a, b). Moreover, writing in a FL presents additional complexities, as writers must navigate various linguistic constraints that can hinder fluency and accuracy. Understanding these cognitive and linguistic challenges is essential for developing effective writing strategies, both in first and foreign language contexts.

Writing in a foreign language

Text production in FL presents unique challenges, as writers must express complex ideas in a language they do not fully master. Unlike native speakers, FL writers must navigate a different orthographic system, unfamiliar grammatical rules, and a limited vocabulary, making the writing process demanding (Kroll, 1990; Porsch, 2020).

Writing in a FL presents numerous challenges for learners, as research has shown notable differences between first language and second language writing processes and text features, including fluency, accuracy, and overall quality (Silva, 1993). FL writers often encounter linguistic constraints related to grammatical accuracy, lexical selection, and syntactic structure, all of which can affect their writing proficiency (Porsch, 2020). To support FL writing development effectively, targeted instructional strategies are essential. Several approaches have been investigated to address these challenges, including explicit grammar instruction, the use of digital tools, and strategy-based training (Reichelt, 2001). Furthermore, researchers have devised and analyzed different measures of fluency, accuracy, and complexity to assess language development in L2 writing (Wolfe-Quintero et al., 1998). To meet educational standards and address specific barriers in FL writing classrooms, instruction should integrate traditional writing tasks with new opportunities and tools for language exploration. This balanced approach not only enhances language proficiency but also fosters engagement and improvement. These insights have important implications for teacher education and instructional practices, guiding educators in developing more effective methodologies for FL writing (Allen, 2018; Nguyen, 2019; Polio, 2017; Porsch, 2020).

Spanish speakers writing in German as a foreign language

Despite these challenges, digital resources play a key role in supporting FL learners and writers. Grammar checkers, translation aids, online dictionaries, and vocabulary-building apps provide immediate feedback, helping learners identify and correct errors, expand vocabulary, and refine sentence structure. These tools promote independent learning, enabling students to practice and improve writing skills at their own pace (O'Brien, 2004; Purcell et al., 2013).

Keystroke logging has gained traction in both educational and research contexts (Baaijen et al., 2012; Leijten & Van Waes, 2013; Lindgren & Sullivan, 2006; Sullivan & Lindgren, 2006; van Waes et al., 2019). This tool provides insights into fluency, pauses, revisions, and cognitive strategies (Leijten & Van Waes, 2013). Additionally, digital tools increase productivity, creativity, and accuracy in writing (Chappelle, 2003; Jones & Hafner, 2012). From automatic grammar and spell checkers to real-time collaboration platforms, these technologies transform both the writing process and the final product (Storch, 2013). Research suggests that grammar and spell checkers aid both native and FL writers by highlighting specific errors and providing explanations (Levy & Stockwell, 2006). In studies by Leijten and Van Waes (2013), integrating real-time searches and feedback into L2 writing tasks improved writing quality, encouraged experimentation with linguistic structures, and fostered more cohesive, fluent texts. Similarly, Wengelin et al. (2014) found that keystroke logging with real-time feedback enhanced engagement and motivation by reducing anxiety and promoting an iterative, reflective writing process.

Learning to write in German can be demanding for Spanish speakers due to the foundational differences in their linguistic structures, vocabulary, and orthography. The origins of German and Spanish reveal distinct developmental paths shaped by different cultural, historical, and linguistic influences. German is part of the Germanic branch of the Indo-European language family, which includes English, Dutch, and the Scandinavian languages. Spanish, on the other hand, belongs to the Romance branch of the Indo-European family, which also includes French, Italian, Portuguese, and Romanian. The grammar and lexicon of the German language present features that can pose a significant challenge for Spanish-speaking learners. In particular, the variability in noun genders and plural forms—often unpredictable—adds considerable complexity. Additionally, German is distinguished by its extensive richness in compound and derived words, which requires a high level of lexical and grammatical precision from learners (Boase-Beier & Lodge, 2003; Eger, 2010; Khaidarova, 2020; Kiyko & Struk, 2022). These features make German a language of considerable difficulty for Spanish speakers, who must navigate morphosyntactic and lexical structures that are often less intuitive than those in their native language. Although both German and Spanish use the Latin alphabet, their written systems differ in several significant ways. German includes unique characters as the Umlauts (ä, ö, ü) and the Eszett (ß), which alter pronunciation and meaning, as well as complex consonant clusters and capitalization of all nouns, regardless of their position in the sentence. Umlauts are essential for indicating certain vowel sounds, the Eszett represents a double “s” sound in specific contexts, and complex Consonant Clusters imply distinction between long and short vowels. Meanwhile, Spanish includes the letter “ñ”,

which represents a distinct nasal sound /ɲ/; several digraphs (e.g., rr, qu, ll); vowel length is not phonemically significant in Spanish, so there is no need to mark vowel length in spelling, however, Spanish uses stress mark (´) to indicate syllable stress (Bravo-Valdivieso & Escobar, 2014). These specific orthographic and grammatical particularities can indeed act as obstacles for Spanish speakers writing in German. They can slow down the writing process and hinder the natural flow of text composition by requiring constant attention to details like capitalization, gender agreement, and case usage.

Our study

To bridge the considered research gap, and in line with the above literature, the aim of the present study was to characterize the process and product of writing in German as an AL language in Spanish speakers. In addition, we tried to find out if the use of digital resources helps to improve writing quality. Such research would contribute to a deeper understanding of how digital resources influence the writing process and the quality, accessibility and efficiency of the product, decisive areas in our rapidly evolving digital landscape. Accordingly, our study seeks to answer the following questions:

1. What are the characteristics of the writing process and product in German as a FL among Spanish-speaking learners?
2. Does the use of digital resources enhance the quality of writing in German as a FL?

By addressing these questions, our study will contribute to a deeper understanding of writing in German as a FL and how digital resources influence the writing process and the quality of the product. This research will offer insights into both theoretical frameworks and practical applications for language learners and educators in our rapidly evolving digital landscape.

Method

Participants

In this study, twenty-one Spanish-speaking participants who were learning German as a foreign language, initially took part. However, two participants were excluded due to recording difficulties, resulting in a final sample of nineteen participants ($M=20.16$, $SD=0.74$; 3 males and 16 females). The participants were recruited from German language classes offered at universities in central Spain.

All of them were studying German as a 6-credit course, which was part of their academic curriculum. They are enrolled in the degrees of Hispanic German Studies, English Studies, Modern Languages and their Literatures, and Translation and Interpreting. Everyone had a consolidated A2.2 German level, and a solid foundation in

English as their second language, aiming to reach, in German language, the B1.1 level of linguistic competence according to the Common European Framework of Reference for Languages (now and forward: CEFR). Although no specific proficiency test was administered immediately prior to the intervention, all participants had previously undergone assessments of their foreign language writing competence as part of their regular academic training. These assessments, conducted independently of the present study, ensured a comparable level of proficiency among participants, allowing us to reasonably assume that there were no significant differences across the four experimental conditions in this regard. Achieving this level allows them to strengthen their knowledge of the phonological, morphosyntactic, and discursive aspects of German. Their training combines a solid theoretical foundation in linguistics with the development of communication skills necessary for the appropriate use of the language in professional contexts related to their field of study. The competencies developed include the ability to identify and analyze the structures and mechanisms governing modern foreign languages. Furthermore, the students enhance their oral and written communication skills in at least two modern languages, reaching a level of proficiency that enables them to perform effectively in professional situations related to their degree. Their respective university study curriculum included cultural insights to enhance their understanding of English- and German-speaking societies. They also deepen their understanding of linguistic, literary, and cultural diversity and learn to write academic, institutional, and administrative texts and reports. Throughout their training, they strengthen skills such as analysis, synthesis, and the practical application of acquired knowledge, as well as the ability to evaluate, interpret, and synthesize data. Participants develop the ability to produce well-structured and coherent texts, comprehend extensive and complex materials, including technical discussions within their specialization in linguistic and literary studies. Additionally, they are capable of understanding implicit meanings in both written and spoken texts. The training utilizes a communicative approach aligned with the guidelines of the CEFR, complemented by focused grammatical analysis. Its goal is to promote an even development across listening, speaking, reading, and writing skills. Learners gain not only practical language proficiency but also a comprehensive and structured understanding of linguistic functions and structures. This sets them apart from other proficient speakers by highlighting the need for a thoughtful exploration of the language's phonological, lexical, grammatical, and discursive elements.

Materials

The task required participants to compose two typed texts on their personal laptops about either *Travelling* and *Celebrations*, ensuring they could write comfortably without difficulties associated with using an unfamiliar keyboard. Participants were instructed to compose a text in German on the given topics, with no restrictions on text length, allowing for a natural and unrestricted writing flow.

Procedure

All writing tasks were conducted in the classroom where participants regularly attended lessons, ensuring a familiar and controlled environment. The laptops were equipped with a Spanish QWERTY keyboard layout and the *Inputlog software* (Leijten & Van Waes, 2013), which records real-time keystroke data within a Microsoft Word environment, set to Calibri font, size 11, with autocorrect disabled.

The study included four experimental settings, as participants were required to write under both assisted and unassisted conditions with digital resources. To ensure balanced conditions regarding topic sequence and resource availability, participants were randomly assigned to four different groups. Half of the participants wrote first about *Travelling* and then about *Celebrations*, while the other half followed the reverse order. Similarly, the use of digital resource assistance was counterbalanced, half of the participants wrote their first composition with digital assistance and their second without, while the other half did the opposite. This counterbalanced design ensured that each participant experienced both writing conditions (with and without digital resources) and both topic sequences, allowing for a systematic evaluation of how digital tools influence foreign language writing performance while minimizing potential biases related to task order or resource availability. These digital resources could be accessed at any stage of the writing process, whether during the initial planning phase, composition, or final revision. Participants were informed that they could utilize digital resources based on their individual decision, allowing them to determine whether and how to integrate tools such as spell and grammar checkers, conjugation aids, writing assistants, and online dictionaries into their writing process. No explicit guidance was provided regarding which specific tools to use, ensuring that participants relied on their own preferences and prior experience with digital writing aids. However, to ensure that the written production accurately reflected each participant's linguistic knowledge and skills, the use of artificial intelligence (AI) tools was strictly prohibited. After receiving verbal explanations from the researcher regarding the objectives and general instructions, and to ensure methodological rigor, each participant was provided in each session with a double-sided card specifying the assigned topic and the digital resource availability condition (e.g., *You have 30 min to write a composition in German on the topic of Celebrations. Your task is to describe and reflect on celebrations*).

Upon completing both writing tasks, participants submitted their Inputlog-generated files to the researcher via email. Additionally, they were asked to provide a qualitative self-assessment reflecting on their personal experience while completing each task, their self-perceived confidence in writing, and the perceived impact of digital resources on their writing process. A general trend of positive feedback regarding the use of digital resources was observed. Participants reported that these tools enhanced their confidence, facilitated idea generation, and provided real-time support in resolving uncertainties. Regardless of the assigned topic, digital resources were perceived as beneficial to the writing process, contributing to greater efficiency and overall ease of composition.

Measures

Several process and product measures were obtained from the text compositions. These measures were categorized as follows:

1. Process measures: Process measures capture the dynamics of writing production, including pausing behavior and keyboard-related activity. They are categorized into Pauses-related and Keyboard-related measures.
 - a. Pauses-related measures
 - *P-Burst length (characters)*: The number of characters generated continuously between writing pauses of 2000 ms or longer, serving as an index of uninterrupted production flow.
 - *Pause percentage*: The proportion of total writing time in which the writer remains inactive.
 - *Number of pauses within words*: The number of pauses (≥ 2000 ms) occurring within a word.
 - *Number of pauses between words*: The number of pauses (≥ 2000 ms) occurring between words.
 - b. Keyboard-related measures
 - *Number of process words*: The total word count generated during active writing.
 - *Time in keyboarding mode*: The total duration the writer actively engages with the keyboard.
 - *Number of words during keyboarding time*: The total number of words typed while actively engaged with the keyboard.
 - *Revisions*: The total number of instances where the writer edited or modified previously generated text.
2. Product Measures: Product measures evaluate the characteristics of the final written output
 - *Total number of product words*: The final word count of the text.
 - *Number of sentences*: The total number of sentences in the final text.
 - *Average sentence length (words)*: The mean number of words per sentence.
 - *Percentage of errors*: The proportion of errors relative to the total word count.
 - *Lexical diversity (content words)*: The measure of lexical richness, calculated using the Giraud index (RTTR: root type-token ratio), which divides the number of unique words (types) by the square root of the total word count (tokens) (Guiraud, 1960).
 - *Text quality assessment*: A judge with advanced proficiency in German evaluated text quality based on a structured rubric. This rubric assessed five key dimensions: structure, content, coherence, syntactic complexity, and

vocabulary pertinence. Each dimension was rated on a four-level scale: Level 4 (Excellent), Level 3 (Good), Level 2 (Sufficient), and Level 1 (Insufficient), see Appendix I. The final text quality score was obtained by combining the partial scores from the evaluated dimensions (structure, content, connectors, and coherence), and subsequently converting the total into a 10-point scale.

Analysis plan

To investigate the effects of the condition factor (with vs. without resources) and the session factor (first vs. second) on multiple dependent variables (process and product measures), a Multivariate Analysis of Variance (MANOVA) was performed. Pillai's Trace was employed as the statistical criterion due to its robustness against violations of the assumption of homogeneity of covariance matrices. In addition, *post-hoc* analysis with *Bonferroni* correction were performed.

For measures showing significant differences between conditions, as identified in the MANOVA, *Pearson's* multiple correlation analyses were carried out to explore relationships between these measures and text quality. This analysis aimed to contextualize and interpret the MANOVA results, uncovering meaningful patterns in the data. Furthermore, two linear regression analyses were conducted—separately for the with-resources and without-resources conditions—to examine how different process and product measures predict text quality. All statistical analyses were performed using JASP software (version 0.19.0; JASP Team, 2024).

Results

Multivariate analysis of variance

Process measures: pauses-related measures

The multivariate tests indicated a statistically significant effect of condition on the combined dependent variables, $F(1, 32) = 5.235, p < .01$. Follow-up univariate ANOVAs and *post-hoc* analysis with *Bonferroni* correction revealed significant differences across condition for P-Bursts length in characters ($p < .05$), with larger P-Bursts in the with than without resources condition; Pause percentage ($p < .001$), with higher percentage of pause in the without than with resources condition; and Number of pauses between words ($p < .05$), with more pauses between words in the without than in the with resources condition. See Table 1.

Table 1 Summary of pause measures scores by condition

	Condition	
	With resources <i>M</i> (<i>SD</i>)	Without resources <i>M</i> (<i>SD</i>)
P-Bursts length	11.566 (4.805)	8.834 (2.780)
Pause percentage	38.312 (13.549)	57.294 (13.103)
N. Pause between words	35.211 (15.285)	47.158 (18.848)

Process measures: keyboard-related measures

The multivariate analysis indicated no statistically significant effect of either the condition or session factors on the combined keyboard-related process measures. See Table 2.

Product measures

The multivariate test indicated a statistically significant interaction of condition by session on the combined dependent variables, $F(1, 34)=12.981, p<.001$. Follow-up univariate ANOVAs revealed significant interaction condition by session for total number of product words, $F(1, 34)=12.981, p<.001$; number of sentences, $F(1, 34)=12.981, p<.001$. The *post hoc* analysis using the *Bonferroni* correction did not reveal any statistically significant difference in the total number of product words between the with-resources and without-resources conditions in either session. For the number of sentences, significant differences were found between the with-resources and without-resources conditions in the second session ($p<.05$), as well as between the first and second session within the without-resources condition ($p<.05$).

Regarding the percentage of errors, session effect, $F(1, 34)=6.05, p<.05$, with more percentage of errors within second session, and condition by session interaction, $F(1, 34)=22.531, p<.001$. The *post hoc* analysis using the *Bonferroni* correction indicated significant differences between with-resources and without-resources conditions in the second session ($p<.001$); between first and second session in the without-resources conditions ($p<.001$); and first with-resources condition and second without-resources condition ($p<.05$). Additionally, a significant effect of condition was observed for text quality, $F(1, 34)=9.770, p<.001$, with better performance in the with-resources condition. These results are summarized in Table 3.

Errors type

Considering the different types of errors (grammatical, lexical, orthographic or punctuation), a multivariate test indicated a statistically significant interaction of condition by session on the combination of errors type, $F(1, 34)=6.990, p<.001$. Moreover, the follow-up univariate ANOVAs, revealed significant interaction condition by session for the percentage of grammatical errors, $F(1, 34)=14.401, p<.001$; where *post*

Table 2 Summary of keyboard measures scores by condition

	Condition	
	With resources <i>M</i> (<i>SD</i>)	Without re- sources <i>M</i> (<i>SD</i>)
Number of process words	188.158 (64.063)	170.579 (48.873)
Time keyboarding mode	754.125 (197.988)	888.139 (310.872)
Word minute active writing	11.620 (2.535)	9.840 (3.889)
Revisions	181.632 (57.884)	197.111 (89.190)

Table 3 Summary of product measures analysis

	Session	Condition	
		With resources <i>M</i> (<i>SD</i>)	Without resources <i>M</i> (<i>SD</i>)
Product words	First	126.889 (16.707)	149.700 (34.580)
	Second	157.300(57.785)	113.778 (23.408)
Number sentences	First	10.556 (2.297)	13.200 (3.327)
	Second	13.300 (3.653)	8.889 (2.421)
Percentage of errors	First	32.469 (4.582)	23.212 (8.207)
	Second	25.100 (11.621)	46.441 (13.022)
Text quality	First	8.009 (1.296)	7.541 (1.279)
	Second	8.667 (1.071)	6.712 (1.112)

Table 4 Summary of analyses for errors

	Session	Condition	
		With resources <i>M</i> (<i>SD</i>)	Without resources <i>M</i> (<i>SD</i>)
Grammatical errors	First	8.899 (3.032)	6.650 (1.898)
	Second	7.123 (1.795)	11.891 (4.891)
Orthographic errors	First	4.815 (2.526)	3.124 (1.202)
	Second	3.541 (2.582)	6.221 (5.565)

hoc Bonferroni analysis correction indicated significant differences between with-resources and without-resources conditions only in the second session ($p < .01$), with fewer grammatical errors in the with-resources condition; and between the first and second session in without resources condition ($p < .01$), with less grammatical errors in the first than in the second session. Regarding the percentage of orthographic errors, a significant interaction between condition and session was observed, $F(1, 34) = 4.138$, $p = .05$. However, post hoc analysis did not reveal any statistically significant differences across sessions or conditions. Results are summarized in Table 4.

Text quality measures

Considering the different measures of text quality (structure, content, connectors, coherence, syntactic complexity and vocabulary pertinence), a multivariate test indicated a condition effect on the combination of text quality elements, $F(1, 36) = 2.510$, $p < .05$. Moreover, the follow-up univariate ANOVAs, with *Bonferroni* correction, revealed interaction mode and condition for structure ($p < .01$), with significant differences between with-resources and without-resources conditions ($p < .05$), and first and second session of without-resources condition ($p < .05$). In addition, we found condition effect on content, $F(1, 36) = 4.840$, $p < .05$; connectors $F(1, 36) = 9.391$, $p < .01$; coherence $F(1, 36) = 8.741$, $p < .01$; syntactic complexity, $F(1, 36) = 4.225$, $p < .05$, and vocabulary $F(1, 36) = 7.385$, $p < .05$. See Table 5.

Table 5 Summary of condition effect for text quality measures

Dimension	Condition	
	With resources <i>M</i> (<i>SD</i>)	Without resources <i>M</i> (<i>SD</i>)
Structure	3.737 (0.452)	3.526 (0.513)
Content	3.526 (0.513)	3.105 (0.658)
Connectors	3.105 (0.737)	2.474 (0.513)
Coherence	3.421 (0.692)	2.737 (0.733)
Syntactic complexity	3.105 (0.809)	2.579 (0.769)
Vocabulary	3.158 (0.501)	2.737 (0.452)
Total text quality	8.355 (1.197)	7.148 (1.244)

Table 6 Bivariate correlations between measures and text quality in both conditions

	<i>P</i> -Bursts L	Pause_Perc	N_Pbw	W_prod	N_sentence	Perc_error	Text_quality
<i>P</i> -Bursts L		-0.440	-0.372	0.620**	0.428	0.205	0.220
Pause_Perc	-0.257		-0.095	-0.541*	-0.614**	0.361	-0.023
N_Pbw	-0.338	0.189		0.293	0.405	-0.508*	0.288
W_prod	0.353	-0.239	0.504*		0.665**	-0.737***	0.486*
N_sentence	0.257	-0.250	0.386	0.707***		-0.711***	0.605**
Perc_error	-0.265	0.482*	-0.418	-0.731***	-0.529*		-0.618**
Text_quality	0.092	0.139	0.047	0.356	0.529*	-0.213	

*** $p < .001$; ** $p < .01$; * $p < .05$

Above diagonal in without resources condition and under diagonal with resource condition

P-Bursts L, *P*-Bursts length in characters; Pause_Perc, PausePercentage; N_Pbw, Number of pauses between words; W_prod, Total number of product words; N_sentence, Number of sentences; Perc_error, Percentage of errors

Multiple pearson correlations

Taking into account the differences between the conditions described above, bivariate Pearson correlations were performed for each condition (with and without resources), in order to know the relationship between measures and text quality. See Table 6.

In the with resources condition, text quality is positively associated with the number of sentences, indicating that a greater number of sentences correlates with higher text quality. Furthermore, the number of sentences shows a positive relationship with the number of product words and a negative relationship with the percentage of errors. Additionally, the number of product words is positively related to the number of long pauses between words, while the percentage of errors is positively related to the percentage of pause time.

In the without resources condition, text quality was associated with the number of sentences, and it was directly related to the number of product words and the percentage of errors. Specifically, a greater number of words, a greater number of sentences, and a lower percentage of errors corresponded to higher text quality. Furthermore, there was a negative relationship between the percentage of errors and the number of sentences, product words, and long pauses between words. The number of sentences showed a positive relationship with the number of product words and a negative rela-

tionship with the percentage of pause time. Finally, product words were negatively related to the percentage of pause time and positively related to the P-Burst length.

Linear regressions

The linear regression analysis using the stepwise method for the with resources condition indicated that the model, with the number of sentences as predictor, was statistically significant, $F(1, 17)=6.617$, $p<.05$, and explained the 23.8% of variance in text quality, Adjusted $R^2=0.238$. The number of sentences, $B=0.191$, $t=2.572$, $p=.020$, CI (95%) [0.034, 0.348] was a significant positive predictor of text quality in the with resources condition. Meanwhile, the linear regression analysis, stepwise method, for the without resources condition indicated that the model with the percentage of errors as predictor was statistically significant, $F(1, 16)=8.947$, $p<.01$, and explained the 32% of variance in text quality, Adjusted $R^2=0.319$. The percentage of errors, $B=-0.046$, $t=-2.291$, $p=.005$, CI (95%) [-0.067, -0.020] was a significant negative predictor of text quality in the without resources condition.

Discussion

The aim of the present study was to characterize the process and product of writing in German as a FL among Spanish speakers. Besides, the study sought to determine whether the use of digital resources improves writing quality. This research contributes to a deeper understanding of how digital tools influence the writing process and its outcomes, including text quality. To achieve the objective nineteen students, recruited from German language courses at universities in central Spain, participated in the study. Participants were given two prompts—Travelling and Celebrations—on which they had to base their written compositions. Each composition task was performed under two different conditions: with and without digital resources.

Results indicated several significant differences between conditions on both process and product measures. On process measures, participants produced more characters per burst in the condition with than without resources; furthermore, when they had the opportunity to use resources, they spent less time pausing than in writing mode, and they committed fewer long pauses between words in the condition with characters than without. Furthermore, considering the product measures, participants in the with-resources condition produced compositions with more sentences, higher quality, and fewer errors than in the without resources condition, especially comparing the second session. Moreover, correlations and regressions seem to indicate that text quality is highly dependent on errors in the without resources condition, which is not the case in the with resources condition.

The findings is in accordance with the notion that text composition is a complex and dynamic process, as described by Chenoweth and Hayes (2001). This process involves the interaction of multiple components, where increased demands on one component can constrain the performance of others. It has been reported that text production in a FL suppose a challenge (Kroll, 1990), where linguistic limitations affect writing process and product. In the present study, participants were required to write

in German as a FL, which posed linguistic limitations (Manchón et al., 2009; Roca de Larios et al., 2002). These constraints likely stemmed from challenges in spelling accuracy, vocabulary, grammar, and syntactic structures inherent to writing in a non-native language. Such limitations likely imposed substantial cognitive demands, leading participants to exhibit a higher percentage of pauses, more frequent long pauses between words, and less characters per burst in conditions without external resources compared to conditions where such resources were available. According to Alves and colleagues (2008), process measures, as pauses, are a reflect the increased cognitive effort and difficulty in managing information when external aids are absent.

Moreover, the linguistic limitations also impact the product, spelling and higher-level of composition as structure, content and organization (Roca de Larios et al., 2002; Sumner et al., 2014). However, the use of digital tools such as online dictionaries, spelling or grammar checkers not only minimized the frequency of errors but also enhanced the quality of their compositions (Chapelle, 2003; Levy & Stockwell, 2006). These findings suggest that digital aids play a vital role in supporting cognitive processes during writing by reducing the demands associated with lexical retrieval or grammatical accuracy (Leijten et al., 2014; Wengelin et al., 2014). Furthermore, the absence of such tools had a more pronounced effect in the second session, which could indicate that participants experienced greater fatigue, making it harder to compensate for linguistic challenges without external support.

As for correlations and regressions, it should be noted that the number of sentences, in the with resources condition, indicates that as the number of sentences increases, the quality of the text improves. This suggests that having more sentences, which likely reflect greater elaboration or a more detailed response, enhances perceived or measured text quality. The availability of resources may have supported participants in expanding their responses, enabling them to produce more content with fewer concerns about errors or lexical limitations. These findings line up with previous literature emphasizing the supportive role of digital tools in increasing writing performance (Leijten et al., 2014; Wengelin et al., 2014). By contrary, in the without resources condition, the negative relationship between the percentage of errors and text quality highlights the critical importance of digital tools in minimizing inaccuracies and improving text quality. These tools, by alleviating the cognitive load associated with grammar, lexical retrieval, and spelling checks, allow writers to focus on higher-order aspects of text composition, such as content development and organization.

In summary, this study highlights the critical role of digital resources in enhancing the writing process and product among Spanish speakers learning German as FL. Participants' ability to produce higher-quality texts with fewer errors and more elaboration when using digital tools underscores the supportive role these resources play in reducing cognitive demands. By facilitating lexical retrieval, grammatical accuracy, and error correction, digital tools allow writers to allocate more cognitive resources to higher-order composition skills, such as content development, coherence, and structural organization. Conversely, the absence of digital tools amplifies the challenges associated with writing in a foreign language, as seen in the greater reliance on error management, more frequent pauses, and shorter bursts of writing activity. These results align with previous literature, emphasizing that writing in a

foreign language is an inherently demanding task, requiring learners to simultaneously manage linguistic, syntactic, and orthographic challenges.

Limitations

While this study offers valuable insights, several limitations should be considered. Firstly, the findings are derived from a specific group of learners, potentially limiting their generalizability to other populations or language contexts. Secondly, the writing tasks, though informative, may not fully reflect the complexity of real-world writing scenarios, especially those requiring extended compositions or engaging with diverse genres. Finally, the study does not account for the long-term effects of digital tool usage on writing development, which represents a valuable avenue for future research.

Building on these findings and addressing the identified limitations, future research could explore the longitudinal effects of digital tool usage on various aspects of writing proficiency, such as vocabulary acquisition, syntactic complexity, and overall text quality. Additionally, examining the role of individual differences, including working memory capacity, language proficiency levels, and cognitive strategies, could provide deeper insights into how these factors influence writing performance under varying conditions. Such research would contribute to a more comprehensive understanding of the interplay between digital tools and writing development in diverse learning contexts.

Appendix I

Criteria		Description
General structure (introduction, development, conclusion)	Excellent (4)	The text presents a well-defined structure with a clear introduction, coherent development, and an adequate conclusion.
	Good (3)	The text has a clear structure, although some sections could be better developed.
	Sufficient (2)	The structure of the text is basic, with missing or unclear parts.
	Insufficient (1)	The text lacks a clear structure, affecting the understanding of the main ideas.
Appropriate content	Excellent (4)	The content is appropriate to the topic and level, demonstrating a solid understanding of the subject matter.
	Good (3)	The content is adequate, although important details are missing.
	Sufficient (2)	The content is relevant but insufficient, covering the topic superficially.
	Insufficient (1)	The content is inappropriate or does not meet the minimum requirements of the topic addressed.

Criteria		Description
Sequence connectors, cohesion, and connection between sentences and paragraphs	Excellent (4)	Sequence and temporal connectors are used variably and precisely, creating excellent cohesion between sentences and paragraphs.
	Good (3)	Connectors are used appropriately, although some may be repetitive or less varied.
	Sufficient (2)	The use of connectors is limited or basic, affecting the fluency and cohesion between ideas.
	Insufficient (1)	There is no use of connectors, or they are used incorrectly, severely affecting the coherence of the text.
Detail and coherence in description	Excellent (4)	Descriptions are detailed, coherent, and easy to understand, allowing for clear comprehension.
	Good (3)	Descriptions are clear, although they could be more detailed or precise.
	Sufficient (2)	Descriptions are basic and lack coherence or detail, making comprehension difficult in some cases.
	Insufficient (1)	Descriptions are vague or incoherent, hindering the overall understanding of the text.
Syntactic complexity of sentences and cohesion	Excellent (4)	Uses complex and varied sentences precisely, maintaining cohesion between ideas and correct grammatical structure.
	Good (3)	Uses simple sentences and some complex ones, though with minor errors that do not affect comprehension.
	Sufficient (2)	Primarily uses simple sentences, with limited attempts at more complex sentences, containing errors that affect cohesion.
	Insufficient (1)	Uses only simple or incorrect sentences, which impacts the cohesion and meaning of the text.
Use of specific, diverse, and comfortable vocabulary	Excellent (4)	Uses specific, diverse, and context-appropriate vocabulary, demonstrating precision and lexical richness.
	Good (3)	Uses adequate vocabulary but limited in variety or precision, with some attempts to use more attractive terms.
	Sufficient (2)	Uses basic or repetitive vocabulary, with few specific or sophisticated words.
	Insufficient (1)	The vocabulary is very limited or inappropriate for the context, affecting the overall comprehension of the text.

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