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Real-Time Analysis of Cognitive Writing Processes in EFL Undergraduates: A Keystroke Logging Study

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Abstract

Research on second and foreign language writing has traditionally focused on the final written product, while the cognitive processes underlying text production remain less explored. This exploratory study investigates the real-time writing processes of Moroccan undergraduate learners of English as a foreign language (EFL) using keystroke logging technology. Five focal participants completed a timed argumentative writing task while their writing activity was recorded using Inputlog. Process indicators including active writing time, pause duration, revision activity, and production bursts were analyzed alongside the quality of the final texts. The findings revealed observable variation in writing profiles among the five participants. Writers who produced higher-quality texts demonstrated greater active writing time, shorter pause durations, and more frequent revision activity, whereas longer pauses and reduced revision behaviors were associated with lower writing performance. The study highlights the potential of keystroke logging as a process-oriented research tool for examining cognitive writing processes in EFL contexts.

1. Introduction

Academic writing is widely recognized as a core competency in higher education and plays a central role in students' academic and professional development. Nevertheless, research consistently shows that many learners struggle to produce well-structured and coherent academic texts (Lea & Street, 1998; Mateos & Solé, 2009). These difficulties often emerge during the complex process of generating ideas, organizing arguments, and translating thoughts into written language. For this reason, examining learners' writing processes can provide valuable insights into the specific points at which writers encounter challenges during idea

generation and textual production (Likens, Allen, & McNamara, 2017). Such insights are particularly valuable because they can inform pedagogical interventions aimed at improving writing proficiency and supporting learners in developing more effective writing strategies (Deane, 2013). Consequently, understanding the cognitive mechanisms that underlie writing is essential for fostering the development of proficient writers.

Despite the growing interest in process-oriented approaches to writing instruction, much research on writing assessment and intervention has traditionally emphasized product-based outcomes, focusing primarily on the quality of the final written text. In many educational contexts, learners' writing is evaluated mainly in terms of the finished product rather than the processes that lead to its production. Although product-oriented approaches have provided important pedagogical insights (Graham & Perin, 2007), they offer limited information about how writers generate, organize, and refine their ideas during the act of composing. As a result, increasing attention has been directed toward process-focused perspectives, which seek to understand writing as a dynamic activity involving multiple cognitive operations that unfold throughout text production. Process-oriented feedback, in particular, has been shown to promote deeper learning and support sustained development in writing skills.

In order to investigate writing processes, researchers have frequently relied on introspective methods such as observations, think-aloud protocols, and retrospective interviews (e.g., Plakans, 2009). These approaches can provide useful insights into writers' strategies and thought processes during composition. However, they also present several limitations. For instance, think-aloud procedures may interfere with the natural flow of writing by imposing additional cognitive demands on participants. Similarly, retrospective methods rely heavily on participants' ability to recall and accurately describe their thought processes after completing the task, which can introduce memory biases and subjective interpretations. Such limitations may reduce the ecological validity of the data and make it difficult to capture writing processes as they unfold in real time.

Recent advances in digital technology have opened new possibilities for investigating writing processes in more objective and unobtrusive ways. One particularly promising method is keystroke logging, which records every keystroke, pause, deletion, and cursor movement that occurs while a writer composes text on a computer. By capturing these actions in a time-stamped sequence, keystroke logging enables researchers to reconstruct the writing process and examine its temporal dynamics in detail. In doing so, it provides fine-grained data on pauses, revisions, and writing bursts, allowing researchers to explore the strategic and temporal dimensions of text production without interrupting the writing process. Despite its considerable potential, the use of keystroke logging remains relatively limited in many educational contexts, including Moroccan EFL settings. The present study seeks to address this gap by examining the writing behaviors of Moroccan undergraduate EFL learners through keystroke logging, with the aim of enhancing understanding of EFL writing processes and informing evidence-based pedagogical practices.

2. Review of Literature

2.1 Cognitive Nature of Writing in EFL Contexts

Writing is not merely a linguistic activity but a complex cognitive process involving multiple, dynamically interacting components. Research on the cognitive nature of writing has

been particularly concerned with how these processes unfold in second or foreign language contexts. A foundational contribution in this area is Flower and Hayes' (1981) cognitive process model, which conceptualizes writing as a recursive problem-solving activity rather than a linear sequence. The model emphasizes continuous interaction among planning, translating, and reviewing processes, highlighting the iterative nature of writing. This perspective is especially relevant for EFL learners, as it explains how more proficient writers engage in ongoing revision, in contrast to the more linear approaches often observed among novice writers.

Earlier models, such as Rohman's (1965) tripartite framework of pre-writing, writing, and rewriting, conceptualized writing as a sequence of distinct stages. Although influential, this model has been criticized for oversimplifying the writing process and failing to capture its recursive nature. Subsequent work by Bereiter and Scardamalia (1987) further advanced this view by distinguishing between novice and expert writers, arguing that expert writers employ more complex, recursive problem-solving strategies, particularly in planning and revision. These distinctions align closely with Flower and Hayes' emphasis on proficiency-related differences in cognitive processing and are especially relevant for understanding fluency and quality in EFL writing.

Despite its influence, Flower and Hayes' model has been critiqued for its limited applicability to novice writers. Berninger (1999), for example, argued that the framework better accounts for skilled writing and offers less explanatory power for developing writers. In response to such concerns, Hayes (1996) revised the original model to incorporate individual, environmental, and affective factors, including motivation and emotional states, thereby offering a more comprehensive account of the writing process in context.

Despite these limitations, the Flower–Hayes model remains a foundational framework for examining the cognitive dimensions of writing and for advancing the view of writing as a recursive and strategic activity rather than a linear one. Understanding these cognitive processes is essential for designing instructional interventions that move beyond surface-level correction and foster deeper strategic and metacognitive engagement. Nevertheless, much writing research continues to privilege final products, leaving the cognitive processes underlying writing – particularly in EFL contexts – relatively underexplored.

2.2 Traditional Methods of Capturing Writing Processes

One of the main challenges in studying cognitive processes is their inherent invisibility: they are internal mental activities that cannot be directly observed or measured. To investigate how individuals read or write, researchers have generally relied on two broad methodological approaches. The first involves self-report methods, in which participants describe their cognitive strategies or thoughts, while the second relies on observation, whereby mental processes are inferred from external indicators such as reading times, eye movements, and keystrokes. Although both approaches provide valuable insights, each has notable limitations, underscoring the difficulty of capturing cognitive activity during language tasks.

A commonly used approach involves eliciting participants' reflections on their thoughts either during task performance (concurrent) or after task completion (retrospective). Techniques such as think-aloud protocols and interviews can yield rich qualitative data but are time-consuming to administer and analyze, often restricting studies to small samples (e.g.,

Plakans, 2009; Spivey, 1990). In contrast, questionnaires and checklists are more suitable for large-scale research due to their efficiency (e.g., Chan, 2013; Chan et al., 2014). Nevertheless, each self-report method presents specific challenges. Concurrent verbalization may disrupt the natural writing process and introduce reactivity (Stratman & Hamp-Lyons, 1994), while retrospective techniques are vulnerable to memory distortion and over-reporting (Harwood, 2009). More broadly, self-report data depend heavily on participants' awareness of their cognitive processes and their ability to recall and articulate them accurately (Smagorinsky, 1994).

In response to these limitations, some researchers have examined writing processes using direct observational methods, such as video recordings (e.g., Bosher, 1998) and screen-capture software (e.g., Chan et al., 2011). These tools allow for the documentation of writing behavior with minimal interference, offering a more naturalistic view of the writing process. However, despite their advantages in reducing reactivity, systematic and large-scale investigations employing these methods remain relatively limited.

2.3 The Emergence of Keystroke Logging

These methodological limitations have prompted researchers to explore more objective and non-invasive alternatives for investigating writing processes, such as keystroke logging. Keystroke logging is a digital research method that captures the physical aspects of writing by automatically recording every keystroke, mouse click, and cursor movement made by a writer as they compose text on a computer. This method generates time-stamped data that reflect the temporal structure and dynamics of the writing process, such as bursts of text production, pauses, deletions, and revisions.

This tool has emerged as a powerful means for examining the cognitive dynamics of writing, as it allows researchers to reconstruct the writing process second by second, providing insight into writing fluency, planning behavior, revision strategies, and overall writing effort (Leijten & Van Waes, 2013). The strength of keystroke logging lies in its unobtrusiveness and objectivity. Unlike verbal reports, it does not interfere with cognitive processing or require self-reporting, thus maintaining the ecological validity of the task. Furthermore, it enables the quantitative measurement of constructs like pause length, writing bursts, and revision patterns, which can be statistically analyzed and correlated with writing quality or learner characteristics.

Despite its wide use in L1 and multilingual writing research, keystroke logging is still rarely employed in EFL contexts in Morocco. Most writing instruction remains focused on surface features and outcome-based assessments, leaving a significant gap in process-oriented, data-driven research. This study seeks to bridge this gap by applying keystroke logging to analyze the writing processes of Moroccan EFL undergraduates, with the aim of identifying patterns that can inform instruction and assessment.

3. The Present Study

The aim of this study is to explore the potential of keystroke logging as a methodological tool for examining writing processes on a small scale within an EFL context. Specifically, the study investigates patterns of writing fluency by examining key temporal indicators such as total active writing time, average pause duration, and the thinking-to-typing ratio, which provide insight into the efficiency of the writing process and the cognitive effort experienced by writers during text production. In addition to fluency-related measures, the study analyzes

pausing behavior during writing, focusing on the timing, location, and duration of pauses, particularly how pauses are distributed within and between words. These patterns may provide indications of the cognitive demands involved in different stages of text production, such as lexical retrieval, planning, or syntactic structuring.

The study also examines revision behavior through patterns of insertions, deletions, and revision bursts captured through keystroke logging, which can offer insight into how writers monitor and refine their texts during composition. Finally, the study compares these process-based indicators with the quality of the final written texts, which are evaluated using an analytic rubric. Rather than testing statistical relationships, this comparison aims to explore whether certain writing behaviors appear to be associated with stronger or weaker writing outcomes.

In line with these objectives, the study addresses the following research questions:

1. What patterns of writing fluency can be observed among Moroccan EFL learners during text production?
2. What pausing patterns emerge during the writing process of Moroccan EFL learners?
3. What revision behaviors can be observed during the writing process of Moroccan EFL learners?
4. How do these writing process indicators compare with the quality of the final written texts?

To the best of the authors' knowledge, this study is among the first to apply keystroke logging to investigate writing processes in the Moroccan EFL context. By focusing on the real-time dynamics of writing rather than solely on the final written product, the study contributes to the growing body of research that seeks to better understand the cognitive processes underlying writing in diverse linguistic and educational settings.

4. Methods

4.1 Participants

This study involves a small sample of five Moroccan undergraduates enrolled in an English Studies program at a public university, specifically two males and three females. All participants are non-native English speakers with Arabic as their first language. The participants were in their second year of university and had successfully completed multiple academic writing courses as part of their curriculum. The selection criteria ensured a relatively homogeneous group in terms of academic level and linguistic background, allowing for a more focused examination of intra-group differences in cognitive writing processes. Participants were recruited on a voluntary basis and provided informed consent prior to data collection. Ethical considerations were strictly observed throughout the study, including assurances of anonymity, the right to withdraw at any stage, and secure handling of keystroke data.

While the small sample size (N = 5) limits the generalizability of the findings, the present study was intentionally designed as a small-scale exploratory investigation aimed at generating preliminary insights into EFL writing processes rather than producing broad statistical generalizations. Given the intensive and fine-grained nature of keystroke logging research, which requires detailed analysis of temporal writing behaviors such as pauses, revisions, and production bursts, small samples are common and methodologically appropriate in process-

oriented writing research (e.g., Leijten & Van Waes, 2013; Sasaki, 2000). The use of a limited number of focal participants enabled close examination of individual writing profiles and facilitated an in-depth analysis of cognitive writing behaviors that might be overlooked in larger-scale studies.

4.2 Design

This study employed an exploratory process-oriented design to examine writing processes during real-time text production. Participants completed a controlled timed writing task while their writing activity was recorded using keystroke logging. Process indicators derived from the keystroke data, including active writing time, pause duration, and revision behavior, were analyzed to describe patterns in participants' writing processes. The quality of the final written texts was evaluated using an analytic rubric. The design allows for an exploratory comparison between writing process indicators and the quality of the written products.

4.3 Instruments

4.3.1 The Writing Task

This writing task was designed to evaluate participants' academic writing performance under timed conditions. Participants were instructed to write a well-organized paragraph of 100–150 words in response to the prompt: "How does social media addiction affect teenagers recently? Does it affect them in a positive or a negative way?" The task required them to develop a clear topic sentence, support their argument with specific examples and explanations, and conclude with a thoughtful final sentence. Additional instructions emphasized the importance of logical organization, coherence, appropriate transitions, correct grammar, spelling, and punctuation, as well as the use of varied sentence structures and sophisticated vocabulary. The time limit for this task was 20 minutes.

4.3.2 Keystroke Logging Software

The primary data collection tool in this study was Inputlog version 9.5.0.1, a keystroke logging software that unobtrusively records participants' writing activity in real time. Inputlog captures detailed behaviors, including key presses, deletions, insertions, pauses, and cursor movements, with each keystroke time-stamped to allow minute-by-minute reconstruction of the writing process. The resulting chronological logs are segmented and annotated to identify cognitive markers such as formulation pauses, lexical retrieval difficulties, and fluency disruptions, providing a more nuanced view than assessments of final texts alone.

Inputlog also enables extraction of key process measures, including total writing time, pause duration and location, and the thinking-to-typing ratio. These indicators reveal information about cognitive load, fluency, and writing efficiency, highlighting moments of planning difficulty, word retrieval challenges, or syntactic structuring issues. By capturing these fine-grained dynamics, Inputlog facilitates a process-oriented investigation of writing, linking cognitive behaviors directly to text quality and uncovering patterns inaccessible through traditional methods.

4.3.3 Writing Quality Assessment

The final written products were evaluated using an analytical scoring rubric adapted by González, Trejo, and Roux (2017) from earlier frameworks (e.g., Jacobs et al., 1981) and informed by the Common European Framework of Reference for Languages. Grounded in the

view of writing as a set of interrelated components (Weigle, 2002), this rubric is particularly suited to EFL/ESL contexts (Hamp-Lyons, 1991; Weigle, 2002). It assesses five dimensions – content, organization, language use, vocabulary, and mechanics/spelling – each rated on a scale from 0 (lowest) to 5 (highest), for a maximum score of 25. This analytic approach allows for the identification of specific strengths and weaknesses in participants' writing. To ensure interrater reliability, all five participant texts were independently rated by two university professors.

4.4 Procedure

The data collection process was carefully structured to ensure consistency, minimize external interference, and capture authentic writing behaviors. The entire procedure was conducted in a quiet, controlled environment and consisted of three phases.

4.4.1 Pre-Writing Phase

Before the writing task began, participants were welcomed and briefed on the overall purpose of the study. They were informed that their keystrokes would be recorded during the task but assured that the study focused on general writing behaviors rather than performance evaluation. Written informed consent was obtained from each participant. After obtaining the informed consent, the participants were then given a short orientation on how the keystroke logging software functioned. A brief hands-on trial session was conducted to familiarize them with the interface and to ensure that they were comfortable typing within the system. This trial was not included in the final data analysis.

4.4.2 Writing Task

Following the orientation, each participant was seated at a separate workstation and asked to complete an argumentative writing task within a 20-minute time limit. The writing prompt was designed to be accessible yet cognitively stimulating, allowing students to draw upon their academic knowledge and personal opinions. The prompt was displayed on the screen throughout the session, and no additional materials or external aids were allowed. During the task, the keystroke logging software recorded all typing activities in real time, capturing data such as:

5. Total active writing time
6. Pausing behavior (duration, location, frequency)
7. Thinking-to-typing ratio
8. Revisions and deletions
9. Overall text development patterns

Participants were instructed to write continuously and to attempt a complete response as a paragraph within the allotted time. They were not permitted to pause the session or ask questions once the writing had started.

4.4.3 Post-Writing Phase

After completing the task, participants were briefly debriefed about the study's aims and offered the opportunity to ask questions or share feedback. The keystroke data were then saved and coded for further analysis. The final written texts were extracted for quality assessment using the analytic rubric. To maintain confidentiality, each participant's data was anonymized

using unique identification codes. Only the researchers had access to the raw keystroke logs and essays. All data were stored securely in accordance with institutional ethical guidelines.

4.5 Data Preparation and Analysis

Based on the recommendations by Leijten et al. (2013), the raw Inputlog data were cleaned by removing any logs not related to the writing task, such as those from the familiarization phase or entering candidate details. After this filtering phase, the keystroke data were analyzed. First, a time-based analysis was conducted for each participant's writing to identify general patterns in their writing process. The second level focused on automatically generated quantitative data from the software, such as total word count, writing fluency, and pause duration.

4.5.1 Fluency Measures

In this study, fluency was primarily assessed using a set of keystroke-based measures that reflect the efficiency and speed of the writing process. These included: (1) total task time, which captures the overall duration of the writing session; (2) execution time, or the time spent actively typing; (3) total number of characters, which indicates the length of the written product; (4) total number of words, another measure of production volume; (5) words per minute (WPM), a core indicator of typing speed during active writing time; (6) product/process ratio, which compares the time spent writing to the total task time, highlighting how much time is spent on the actual writing versus pausing; and (7) mean burst length, the average number of characters typed between pauses. These measures were selected to give a comprehensive view of the writer's fluency, focusing on the overall speed, efficiency, and rhythm of the writing process.

In addition, production bursts (P-bursts) were examined as an indicator of writing fluency. Production bursts refer to continuous segments of text production occurring between pauses that exceed the predefined pause threshold. A higher number of production bursts may indicate a more fragmented writing process characterized by frequent interruptions, whereas fewer bursts may reflect longer periods of continuous text generation.

The analysis also considered revision bursts (R-bursts), defined as clusters of revision actions such as deletions, insertions, or substitutions occurring within a relatively short period during text production. These bursts provide insight into moments when writers actively monitored, evaluated, and modified their developing texts.

4.5.2 Pauses in Writing

Pauses were analyzed as an additional indicator of fluency. Following common practices in similar studies (e.g., Leijten & Van Waes, 2013), pauses of 2 seconds or more were considered significant. The analysis focused on (1) mean pause duration, which reflects the average length of pauses that exceeded the 2-second threshold, and (2) the patterns of pauses, including when, where, and how long each pause occurred. Pauses may indicate moments of reflection, cognitive processing, or difficulty, and their frequency and length can provide valuable insight into the writer's cognitive load or fluency.

4.5.3 Revisions in Writing

Revisions were also considered a key aspect of fluency. Inputlog allows for the tracking of changes made during the writing process, such as insertions, deletions, and edits. The frequency and timing of revisions were analyzed to assess how often the writer made changes

to the text. A high frequency of revisions can indicate disfluency, suggesting that the writer may have struggled to produce text without frequent corrections. On the other hand, fewer revisions may indicate smoother, more fluent writing. These revisions were manually coded to provide a deeper understanding of the cognitive processes involved in the writing task.

5. Findings

Before presenting the data analysis, a sample of the raw data that Inputlog generates will be shown. Table 1 presents raw data for a sample of keystrokes, which provides detailed insights into the writing process, including action and pause durations, as well as the specific locations where pauses occur. For instance, as shown in Table 1, a within-word pause of 581 milliseconds occurred before typing the letter "A" at position 118. This was followed by a 247-millisecond pause between words before the spacebar was pressed, and a 540-millisecond pause before typing the letter "T" at position 120. These micro-level data points allow for a granular analysis of writing fluency and cognitive load during composing.

Table 1: Sample of Inputlog's General Analysis Output

Type	Output	Start time	Start clock	End time	End clock	Action time	Pause time	Pause location	Pause location full	Position	Do leng
Keyboard	A	148431	00:02:28.431	148543	00:02:28.543	112	581	1	Within words	118	11
Keyboard	Space	148678	00:02:28.678	148810	00:02:28.810	132	247	3	Between words	119	12
Keyboard	T	149218	00:02:29.218	149336	00:02:29.336	118	540	2	Between words	120	12

5.1 The Patterns of Writing Fluency

Table 2 summarizes several indicators of writing fluency across the five participants, including total process time, total pausing time, active writing time, thinking-to-writing ratio, text length, and production bursts. These measures provide insight into how participants managed the writing task and how their writing processes differed in terms of efficiency and cognitive effort.

Overall, clear variation in writing fluency can be observed among the participants. Participant 1 recorded the longest total process time (21.05 minutes) and also demonstrated the highest amount of active writing time (15.08 minutes), suggesting a relatively sustained writing process with fewer extended pauses. In contrast, participant 2 completed the task in the shortest amount of time (13.50 minutes) and spent 8.45 minutes actively writing.

Participants 3, 4, and 5 showed a different pattern, with a substantial proportion of their writing sessions devoted to pauses rather than active text production. Participant 5, in particular, exhibited the longest cumulative pause duration (11.01 minutes), followed by participant 4 (9.33 minutes) and participant 3 (8.03 minutes). These longer pausing periods may reflect greater cognitive effort during idea generation or formulation.

The thinking-to-writing ratio further highlights these differences. Participant 1 displayed the lowest ratio (26.66%), indicating a relatively fluid writing process with less time spent pausing relative to writing. By contrast, participants 3, 4, and 5 showed considerably higher

ratios, exceeding 50%, suggesting a more interrupted writing rhythm characterized by frequent or extended pauses.

Differences were also observed in text production. Participant 2 produced the longest text, with 1,068 characters and 201 words, while participant 5 produced the shortest output (478 characters and 87 words). In terms of production bursts (P-bursts), participant 4 recorded the highest number (97 bursts), followed by participant 5 (85 bursts). Participant 2 produced the fewest bursts (43), which may indicate longer continuous writing segments between pauses rather than frequent short bursts.

Overall, these indicators reveal substantial variation in writing fluency across participants, suggesting differences in writing rhythm, cognitive effort, and text production strategies during the task.

Table 2: General Fluency Measures of all the Participants

Measures	1	2	3	4	5
Total Process Time	21.05	13.50	15.16	17.49	18.14
Total Pausing Time	5.37	5.07	8.03	9.33	11.01
Total Active Writing Time	15.08	8.45	7.13	8.15	7.13
Thinking-to-writing ratio	26.66	36.73	52.69	53.63	60.42
Total number of characters	732	1068	589	601	478
Total Number of words	129	201	115	106	87
P Bursts	70	43	69	97	85

5.2 The Pausing Patterns

Table 3 presents measures of pausing behavior across the five participants, including the total number of pauses, average pause duration, and the location of pauses within the text. These indicators provide insight into the cognitive demands experienced during the writing process.

The total number of pauses varied considerably among participants. Participant 4 exhibited the highest number of pauses (96), followed by participant 5 (86), participant 1 (70), and participant 3 (69). In contrast, participant 2 recorded the fewest pauses (44), suggesting a more continuous writing process with fewer interruptions. A higher number of pauses may reflect increased hesitation during lexical retrieval, planning, or decision-making while composing.

Pause duration also differed across participants. Participant 5 displayed the longest average pause duration (5,381 ms), followed by participant 3 (4,685 ms) and participant 4 (4,246 ms). Participant 1 recorded the shortest average pause duration (3,749 ms), which aligns with their relatively higher writing fluency and lower thinking-to-writing ratio. These differences suggest that some participants experienced longer periods of cognitive processing before continuing to write.

An examination of pause locations further illustrates how writers managed different stages of text production. Within-word pauses were most frequent among participants 3, 4, and 5, which may indicate difficulties related to spelling, typing, or lexical retrieval. In contrast,

participants 1 and 2 exhibited relatively few within-word pauses, suggesting more automated text production.

Between-word pauses were the most common across participants and were particularly frequent for participants 4 and 5. Such pauses are typically associated with short-term planning or sentence formulation. Pauses between sentences were comparatively rare for all participants, suggesting that most pauses occurred during local planning rather than during larger-scale discourse organization.

Miscellaneous pauses, which often occur during revision actions or cursor movements, were most frequent among participants 4 and 1. These pauses may reflect moments of self-monitoring or text revision during composition.

Taken together, these pause patterns suggest notable differences in writing rhythm among the participants. Writers with fewer and shorter pauses, such as participant 2, appear to demonstrate a more fluent writing process, whereas writers with more frequent and longer pauses may experience greater cognitive demands during text production.

Table 3: Pausing Measures of the Participants

Metrics	1	2	3	4	5
Total Number of Pauses	70	44	69	96	86
Average Pausing Duration	3749	4156	4685	4246	5381
Within-word pauses	8	5	20	18	22
Between-word pauses	30	21	23	40	36
Between-sentence pauses	4	6	7	3	1
Miscellaneous Pauses	17	7	8	22	8

5.3 Revision Patterns

Table 4 summarizes the revision behavior observed across the five participants, including the number of deletions, insertions, revision bursts, and the mean number of revisions per minute. These indicators provide insight into the extent to which participants engaged in monitoring and modifying their texts during the writing process.

Clear variation in revision behavior was observed across participants. Participants 1 and 2 displayed the most revision-intensive writing patterns. Participant 1 recorded the highest number of deletions (97), followed closely by participant 2 (90). Participant 4 produced 70 deletions, while participant 3 made 57. In contrast, participant 5 made considerably fewer deletions (14), suggesting a markedly lower level of real-time editing during text production. Higher deletion rates may indicate ongoing evaluation of linguistic accuracy, word choice, or textual coherence while writing.

A similar pattern emerged for insertions, which reflect the addition of newly considered or previously omitted content. Participant 1 again produced the highest number of insertions (18), followed by participant 2 (15). Participant 3 recorded the lowest number of insertions (6), while participant 5 produced relatively few modifications overall. When considered together with deletion behavior, these patterns suggest that participants 1 and 2 engaged in a more dynamic writing process characterized by continuous adjustments and refinements.

Differences were also evident in the rate of revisions over time. Participant 2 demonstrated the highest mean number of revisions per minute (7.4), indicating frequent small-scale modifications during composition. Participant 1 followed with 5.4 revisions per minute, suggesting an active monitoring process throughout writing. In contrast, participant 5 exhibited a notably low revision rate (0.77 revisions per minute), reinforcing the observation that this participant engaged in relatively limited revision activity.

The number of revision bursts (R-bursts), defined as clusters of multiple revision actions occurring within a short time span, further illustrates these differences. Participant 1 recorded the highest number of revision bursts (90), closely followed by participant 2 (86). These concentrated episodes of revision may reflect moments of focused problem-solving or restructuring within the text. By comparison, participant 5 produced only 15 revision bursts, suggesting a more linear writing process with fewer interruptions for revision.

Overall, the results indicate substantial variation in revision behavior among participants. Participants 1 and 2 demonstrated the most revision-intensive writing patterns, characterized by frequent deletions, insertions, and clustered revision episodes. Such behavior may reflect a higher level of metacognitive engagement, including monitoring for linguistic accuracy, clarity, and coherence. In contrast, participant 5's minimal revision activity suggests a different writing profile, potentially characterized either by greater writing fluency or by a lower tendency to critically revise the developing text.

Table 4: Revision Measures of the 5 Participants

Measures	1	2	3	4	5
Deletions	97	90	57	70	14
Insertions	18	15	6	8	12
Mean number of revisions per minute	5.4	7.4	4.1	4.3	.77
Number of R Bursts	90	86	59	65	15

5.4 Writing Quality

Table 5 presents the writing quality scores across five dimensions: content, organization, use of language, use of vocabulary, and mechanics and spelling. The results reveal noticeable variation in writing performance among the five participants.

Participant 2 achieved the highest overall score (20/25), demonstrating well-developed ideas, clear organization, and relatively strong control of vocabulary and grammatical structures. Participant 4 obtained the second-highest score (15/25), followed by participant 1 (14/25). In contrast, participants 3 and 5 received the lowest scores, with totals of 11/25 and 10/25 respectively.

A closer examination of the rubric dimensions suggests that participants generally performed better in content and organization, indicating an ability to generate ideas and structure them in a coherent manner. However, lower scores were observed in linguistic aspects of writing, particularly in vocabulary use, grammatical accuracy, and mechanics. Difficulties in spelling and surface-level correctness were especially evident among several participants.

Overall, these results suggest that while participants were able to express and organize ideas to some extent, limitations in linguistic accuracy and lexical control affected the overall quality of their written texts.

Table 5: Results of Individual Elements and Total Scores of the Analytic Rubric for all Participants

Participant	Content	Organization	Use of Language	Use of Vocabulary	Mechanics and Spelling	Total
1	4	3	2	3	2	14
2	5	4	4	4	3	20
3	4	2	2	2	1	11
4	4	4	3	3	1	15
5	3	3	2	1	1	10

5.5 Time-Based Graphic Representations of Writing Process

In addition to numerical indicators, Inputlog also generates time-based visualizations that illustrate the temporal dynamics of writing. These visualizations allow researchers to observe how text production unfolds throughout the writing session.

Figure 1 presents the writing process of the highest-performing participant by plotting process time against character production. The steady upward progression of both the process and product lines suggests relatively continuous text generation throughout the task. Occasional flat segments and pause markers indicate brief interruptions, which may correspond to moments of planning or local revision. Cursor movements toward the end of the session suggest a final phase of revision, although the overall pattern shows relatively limited focus switching. Taken together, these features indicate a comparatively smooth and stable writing process.

Figure 2 illustrates the writing session of another participant whose process appears more interrupted. In contrast to Figure 1, the graph shows slower text production, a higher density of pauses, and more frequent cursor movements across the text. Although writing progressed throughout the task, the distribution of pauses and the non-linear cursor activity suggest a more fragmented writing process, potentially reflecting greater cognitive effort during planning and revision. Overall, the visual comparison between the two figures highlights differences in the temporal organization of writing among participants.

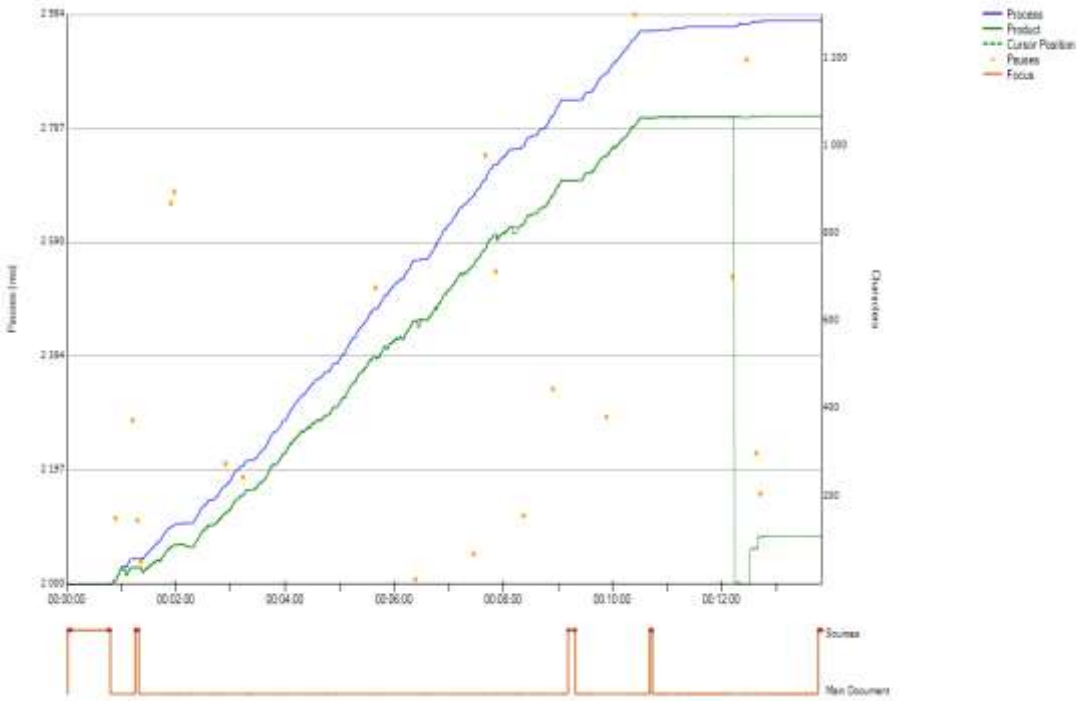

Figure 1: Process Graph of the Participant with the Highest Writing Quality

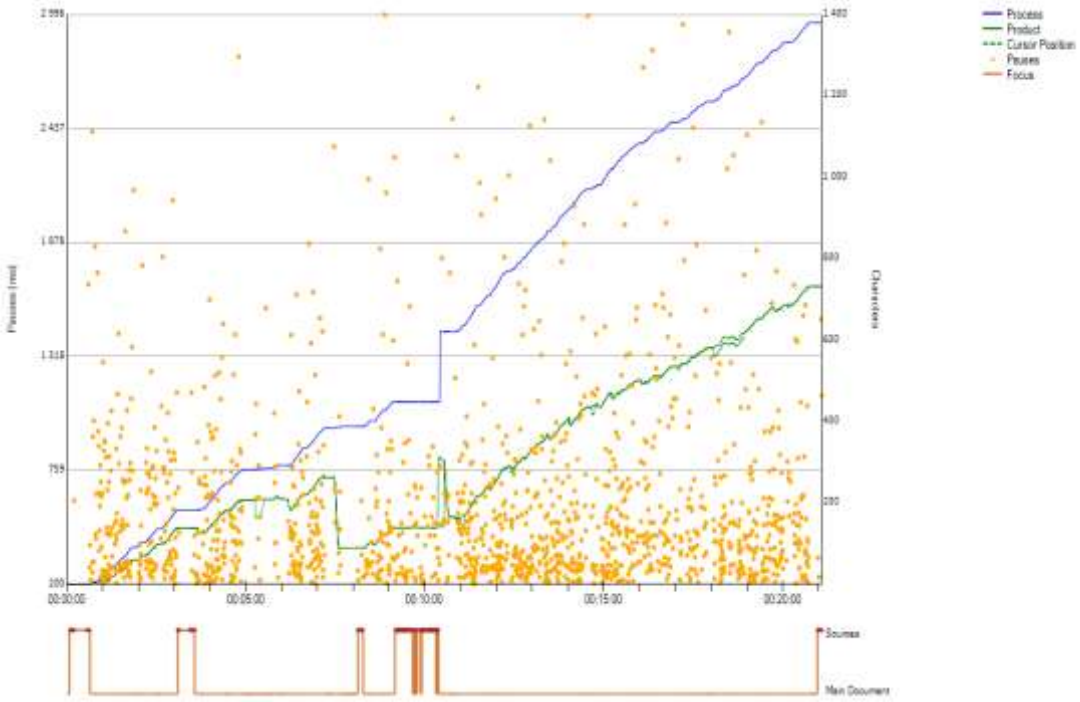

Figure 2: Process Graph of the Participant with the Lowest Writing Quality

5.6 Writing Performance and Process Indicators

To explore how writing processes may relate to performance, the writing quality scores were examined alongside the fluency and pausing measures presented earlier. Descriptive comparisons suggest that participants who demonstrated higher writing fluency and fewer interruptions tended to achieve higher writing scores.

For example, participant 2, who obtained the highest writing score (20/25), also produced the longest text and demonstrated relatively efficient text production with fewer pauses compared to several other participants. Similarly, participant 1, who achieved the third-highest

score (14/25), displayed a relatively low thinking-to-writing ratio and a higher proportion of active writing time.

In contrast, participants with lower writing scores tended to exhibit longer pausing times and higher thinking-to-writing ratios. Participant 5, who received the lowest score (10/25), showed the longest cumulative pause duration and the highest thinking-to-writing ratio, indicating a more interrupted writing process.

Although the small sample size does not allow for statistical generalization, these patterns suggest that higher writing performance may be associated with more fluent text production and fewer extended pauses during the writing process.

6. Discussion

The present study explored the potential of keystroke logging to examine the real-time writing processes of Moroccan EFL learners and to describe how different writing behaviors may relate to variations in text quality. The analysis of fluency indicators including pausing patterns, revision behavior, and writing quality scores contributes to providing preliminary insights into how writing unfolds during composition and how these processes may influence the final written product.

6.1 Individual Writing Profiles and Writing Processes

The analysis revealed noticeable differences in writing profiles among the five participants. These differences were reflected in the balance between active writing time and pausing, the frequency and duration of pauses, and the extent to which writers engaged in revision during composition. Keystroke logging made it possible to capture these moment-by-moment dynamics and to examine how they corresponded with variations in writing quality.

Participant 2 demonstrated the most fluent writing process and achieved the highest overall writing score, as this participant produced the longest text within a relatively short process time and exhibited comparatively fewer and shorter pauses. Such patterns suggest efficient lexical access and greater automaticity in lower-level writing processes. According to cognitive models of writing, when lower-level processes such as spelling and lexical retrieval become more automatic, writers can allocate more cognitive resources to higher-order processes such as idea development and text organization (Field, 2004; Kellogg et al., 2013; Matsuhashi, 1981; Sasaki, 2000). The combination of writing fluency and effective text development observed in this participant is consistent with these theoretical perspectives.

Participant 1 displayed a similar profile, although with a longer overall process time. Despite spending more time on the task, this participant maintained a relatively high proportion of active writing time and engaged frequently in revision. The presence of purposeful revisions alongside sustained writing activity suggests an ongoing monitoring process during composition. Such behavior may reflect metacognitive engagement, in which writers continuously evaluate and refine their developing texts.

In contrast, participant 5 demonstrated the least fluent writing profile and produced the lowest-quality text. This participant showed the longest cumulative pause duration, the highest thinking-to-writing ratio, and minimal revision activity. The combination of extended pauses and limited text production suggests substantial cognitive effort during idea generation or language formulation. Previous research has shown that longer pause durations are often

associated with increased cognitive load during writing tasks (Wallot & Grabowski, 2013; Alves et al., 2007; Wengelin, 2006). The pattern observed here may therefore reflect difficulties in lexical retrieval or sentence construction during L2 writing.

Participant 4 presented an interesting profile in which relatively fragmented fluency coexisted with comparatively high writing quality. Although this participant exhibited frequent pauses and interruptions during writing, the text received the second-highest quality score. One possible explanation is that pauses and revisions were used strategically to plan and refine the text. Previous research has suggested that pauses can serve important planning functions during writing, allowing writers to organize ideas and revise emerging content (Rijlaarsdam, Couzijn, & Van den Bergh, 2004). In this case, the pauses may have contributed to improved coherence and clarity despite disruptions in writing fluency.

Participant 3 demonstrated moderate performance across both process and product measures. Frequent pauses combined with relatively limited revision activity resulted in a shorter text and an average writing quality score. This profile may reflect a writing process in which cognitive effort is directed toward generating ideas rather than refining or expanding them.

Across participants, between-word pauses were more frequent than within-word or between-sentence pauses. This distribution suggests that pauses often occurred during lexical retrieval or short-term planning at the sentence level. Within-word pauses were comparatively rare, which may indicate that the motor aspects of text production, such as typing and spelling, were relatively automated for most participants. These findings align with previous research showing that pause location can provide insight into the level of cognitive processing occurring during writing (Wengelin, 2006).

6.2 Process Indicators and Writing Performance

In addition to examining individual writing profiles, the study also explored how key writing process indicators were associated with variations in text quality. Although the small sample size prevents statistical generalization, descriptive comparisons suggest several patterns linking writing behaviors to writing performance.

First, higher writing quality appeared to be associated with greater writing fluency. Participants who spent a larger proportion of time actively composing rather than pausing tended to produce higher-quality texts. This pattern is consistent with cognitive theories of writing, which propose that fluent text production allows writers to devote more cognitive resources to higher-level processes such as organizing ideas and refining arguments (Kellogg et al., 2013).

Second, pause behavior appeared to play an important role in shaping writing outcomes. Participants with longer and more frequent pauses generally obtained lower writing scores. Longer pauses may reflect increased cognitive effort during lexical retrieval, sentence planning, or grammatical encoding. Previous research has similarly shown that extended pause durations are often associated with increased cognitive load in writing tasks (Wallot & Grabowski, 2013; Alves et al., 2007). The findings of the present study suggest that pause duration may be particularly informative in distinguishing more fluent from less fluent writing processes.

Third, revision behavior appeared to be associated with writing quality. Participants who produced higher-quality texts tended to engage more actively in revision during composition, as reflected in higher frequencies of insertions and deletions. These revision actions may indicate ongoing monitoring and restructuring of the developing text. Such behavior has been linked to greater metacognitive control during writing, where writers evaluate their texts and make adjustments to improve clarity and coherence (Rijlaarsdam, Couzijn, & Van den Bergh, 2004).

The time-based visualizations generated by Inputlog further illustrate these differences in writing processes. The writing session of the highest-performing participant showed a relatively continuous and linear progression of text production, characterized by sustained writing bursts and limited interruptions. In contrast, the writing sessions of lower-scoring participants displayed more fragmented patterns, with frequent pauses and irregular cursor movements. These visual patterns reinforce the quantitative findings and provide additional insight into the temporal organization of writing behavior.

Taken together, the findings suggest that writing performance may be associated with a combination of fluent text production, manageable pause durations, and active revision strategies. However, given the exploratory nature of the study and the small number of participants, these observations should be interpreted as preliminary indications rather than definitive relationships.

7. Conclusion

7.1 Summary of Findings

This study explored the writing processes of Moroccan EFL learners using keystroke logging in order to examine how writing fluency, pausing behavior, and revision activity relate to variations in text quality. The findings suggest that differences in writing performance are associated with distinct patterns of writing behavior during composition. Participants who spent a greater proportion of time actively composing rather than pausing generally produced higher-quality texts, while longer pauses and fragmented writing patterns were more common among lower-performing writers. Revision behavior also appeared to play a role in shaping writing outcomes, suggesting that purposeful monitoring and restructuring may contribute to improved text quality.

7.2 Practical Applications

This paper demonstrates the potential of keystroke logging as a real-time, process-based tool with valuable applications in both writing research and pedagogy. By capturing fine-grained data on pauses, revisions, and writing bursts, keystroke logging enables a deeper examination of the cognitive processes and strategies underlying text production. Importantly, it offers a means of investigating writing processes without relying on more intrusive methods such as think-aloud protocols.

In educational contexts, keystroke logging may also serve as a valuable formative feedback tool. Teachers could analyze learners' writing patterns to identify issues such as excessive pausing, limited fluency, or insufficient revision and provide targeted, individualized feedback. Visualizations of writing timelines, for example, may help students recognize where they hesitated or struggled, thereby supporting instruction in planning, drafting, and editing

strategies. Such process-oriented feedback has the potential to promote greater metacognitive awareness of writing processes and support the development of more effective writing strategies. However, the effectiveness of these pedagogical applications was not investigated in the present study and should be explored in future research.

7.3 Limitations and Further Research

While this study offers valuable insights into EFL writing processes through keystroke logging, several limitations should be acknowledged. First, the small sample size (N = 5) limits the statistical power and generalizability of the findings. As an exploratory study, the results should be interpreted cautiously and viewed as indicative rather than conclusive. At the same time, the small-scale design enabled a fine-grained analysis of individual writing behaviors, allowing for close examination of how keystroke data and final products interact to reveal distinct writing profiles.

Second, the study does not make definitive claims about overall writing proficiency based on a single writing task. Writing performance is influenced by multiple factors, including task type, genre familiarity, and individual strategies. Future research should incorporate multiple tasks across genres and levels of difficulty to obtain a more comprehensive assessment of writing ability. Additionally, participant-related variables such as gender, typing speed, digital literacy, working memory capacity, and vocabulary size were not examined but may have influenced fluency and cognitive load; these factors should be systematically controlled or explored in future studies.

Finally, although keystroke logging provides a powerful and unobtrusive means of capturing writing processes, relying on this method alone may lead to an overemphasis on mechanical indicators (e.g., pause duration, revision frequency) at the expense of underlying cognitive and contextual factors (Leijten & Van Waes, 2013). To address this limitation, future research should adopt multimodal approaches that combine keystroke logging with complementary methods such as eye tracking, which can reveal attention and reading behavior during writing. Such integration would offer a more comprehensive understanding of the cognitive and affective dimensions of writing.

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